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13. ABSTRACT *(Maximum 200 words)*
Successful operation of aircraft in normal and emergency situations is critical to completing mission requirements as well as to the safety of aircrew and equipment. On average, the upper body strength of females is about 50-60 percent of males. No strength standards are currently in place to assure individuals are capable of actuating foot and hand controls. This study will determine strength critical aircraft tasks, develop criterion tasks that replicate critical tasks and can be used as a screening tool, develop a field screening test battery, and develop a remedial physical conditioning program. Data collected thus far indicate a definite need for this type of research. Results have shown the Navy aviation candidate population is similar to the general population in that significant strength differences were seen between males and females. A screening device has been designed and is being built. Motion analysis data for all critical aviation tasks has been collected. Over 426 subjects have been tested thus far to develop a strength database and another 300 subjects will be tested in the near future. Pending future funding, work will continue in FY96 and products will be transitioned to the fleet as they are finished.

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TABLE OF CONTENTS

INTRODUCTION

Problem:

Current DoD policy authorizes both male and female pilots and Naval Flight Officers (NFO) to compete for combat aircraft assignment (1). At present the only physical strength/endurance tests utilized in naval aviation are the Navy Physical Readiness Test (PRT) (2) and specific physical training activities in the Naval Aviation Schools Command (NASC) physical training curriculum. Although both programs are gender and age normed, they have not been validated against specific aviation occupational strength requirements. Physical strength is required for routine and emergency tasks (e.g., high-G maneuvers, manual landing gear extension, ejection seat actuation, manual opening and closing of hatches and canopies) in all naval aircraft. Current physical testing may not predict success for pilots/NFO's in accomplishing specific fleet aircraft tasks. This creates a serious safety concern as (combat) aviation opens to a wider population base.

A recent memo from the Assistant Secretary of the Navy stated:

> "We are faced with a multitude of challenges, as we strive to integrate women into Navy and Marine Corps aircraft. Equipment and cockpit designs are based on male sizing. This severely limits the pool of eligible female pilots. New pipeline training aircraft (Joint Primary Aircraft Training System [JPATS] and T-45) will accommodate a much wider range of eligible females. As our flight experience expands, we are identifying additional female concerns and issues. The following is a list of just some of these:
>
> -Safety and Survivability
> -Specific physiological and psychological needs
> -Clothing and protective equipment
> -Cockpit fit and compatibility/assignment potential in fleet aircraft
>
> These issues are not Navy and Marine Corps unique but shared by the other services."

This study will address two issues: Cockpit compatibility and fleet aircraft assignment. This concern was addressed in a recent message (CHNAVPERS 100001Z Aug 93) from the Bureau of Naval Personnel (BUPERS). The message asked the Bureau of Medicine and Surgery (BUMED) to begin research to address this issue, and for NAMRL to work with the Naval Aviation Schools Command (NASC) to develop a plan of action for research.

Previous work:

Previous studies have shown strength differences between men and women especially in upper body muscles. In a review of literature, Laubach (3) reported that women were found to range from 35 to 79% of men's upper extremity strength, averaging 55.8%. Teves et al (4) found, when normalized for body weight, females were 75% as strong as males on isometric measures. Robertson (5) reported greatest strength differences between men and women on upper torso dynamic strength tests-- push-up, pull-up, and bent arm-hang where women's means were 10, 5, and 23 percent respectively of mens. Most of these studies concluded the strength differences were due to smaller muscle mass. Muscle mass differences are also seen in smaller stature men as well as women, so strength screening standards should address individual characteristics without reference to gender. McDaniel (6) found that men were stronger than women when measured on 10 different aircraft tasks. This study concluded that the correlation between strength and size is low and that cockpit designers/evaluators should select subjects for their strength characterics. Whether the issue is strength (dependent on size-Robertson or independent of size-McDaniel), there is a need for task specific gender neutral strength testing.

Purpose:

The purpose of this research is to develop for the Chief of Naval Air Training (CNATRA) aviation occupational standards that will identify individuals capable of meeting specific strength performance requirements to safely conduct flight duties as pilots and naval flight officers (NFO). Performance requirements will incorporate instantaneous strength, sustained strength and endurance for routine, emergency, and survival situations in all naval aircraft. Subsequent to development of the standards will be the development of a physical conditioning program that will enable candidate pilots/NFO's to meet or exceed the minimum requirements.

The proposed research program will identify strength/endurance requirements to safely perform the duties of a pilot/NFO. Requirements will be based on factors provided by fleet aircrew for each naval aircraft. It should be noted that strength and endurance factors are <u>only a part</u> of the overall identified problem. Other occupational standards (e.g., crew station accommodation, anthropometric compatibility, egress system safety considerations) integrate with strength/endurance standards, and need to be examined in other research programs.

Methods of approach:

The approach to this project is to build on what other projects have done in this area and develop a program that is unique to military aviation. We will develop requirements for aviation by going to experts in aircraft operation. Once requirements are identified, occupational performance criterion tests and strength test batteries will be developed, validated and established as strength performance standards. A subsequent effort would develop a remedial physical conditioning program, allowing candidates an opportunity to meet or exceed the occupational standards strength test battery. The final products of the proposed research project will be identification of strength requirements for all Navy aircraft, a device to measure strength capability, a strength test battery for use at remote sites to predict success in passing requirements, and a remedial physical conditioning program for candidates who cannot initially pass requirements. A list of strength requirements will be transitioned to the Chief of Naval Air Training (CNATRA) and BUPERS for aircraft pipeline selection. A device for determining if aviation candidates possess strength required for performance aircraft duties will be transitioned for use by NASC. The strength test battery will be transitioned to the Chief of Naval Education and Training (CNET) to be used at Reserve Officer Training Corps (ROTC) sites and the US Naval Academy. The remedial physical conditioning program, designed to increase strength for individuals not meeting standards, will also be transitioned to NASC.

The ultimate benefit the proposed research would bring to the Navy is enhanced safety. Results will allow the Navy to safely open aircraft to a wider segment of the general population. Some personnel will be restricted from flying certain aircraft because of strength/safety concerns, but restrictions will be based on scientifically derived standards that will be applied equally to all naval aviation applicants.

EXPERIMENTAL METHODS

The program is being conducted in three phases. Phase I identified critical occupational performance tasks and associated strength requirements, and developed criterion tasks that replicate the identified occupational standards of performance. Completion of Phase I will provide a product for use by CNATRA to evaluate initial pilot/NFO candidate performance screening. Phases II & III validate results of Phase I and create a remedial physical conditioning program.

Phase II will also develop a strength testing battery (STB), cross validate the criterion tasks and strength tests, and provide a final STB. Phase III will develop a remedial physical conditioning program to enable candidate pilots/NFO's to meet or exceed the requirements of the STB. A final technical report will be prepared completing Phase III.

SEQUENTIAL BREAKDOWN - PHASE I

1. Background/Literature Review:

A review of pertinent military, sports medicine and human factors literature was accomplished. State-of-the-art strength measuring devices were identified.

2. Fleet-Wide Survey:

Fleet replacement squadrons(FRS)/aircraft type model managers were contacted for determination of aircraft-specific occupational strength requirements. The survey identified aircraft actions that required strength, then follow-up was done to document how much strength was required. It was anticipated that most forces required could be derived from historical engineering data for each aircraft. On-site force measurements were be accomplished for forces unavailable. Force measurement tools were designed by NAWC (AD) Patuxent River. Liaison with aricraft contractors, FRS simulator activities, Navy aircraft engineers, etc. for acquiring force measurements was done.

3. Field Visits:

Criterion task(s) in aircraft were documented (videotape, photographs, etc.) Three-dimensional motion analysis was conducted for each of the identified critical tasks. State-of-the-art biomechanics techniques and equipment were employed to accomplish this analysis. Data collected will be used to assist in screening tool design, development of the strength test battery, and development of the remedial strength conditioning program.

Instrumentation:

a. Video cameras were placed in different views to capture the critical task in each cockpit. A control object was filmed for conversion of real values from video images.

b. After data collection the 2 dimensional video images were captured from each view, specific body landmarks were digitized, and the video images were transformed. The raw three-dimensional data points were smoothed with a Butterworth digital filter set at 6 Hz. All data analysis was performed with the Ariel Performance Analysis System.

c. Linear and angular displacements, velocities, joint forces and moments, were determined for specific joints related to the task analyzed.

- Linear displacement in the X,Y,Z directions was determined after plotting the digitized points of the joint coordinates.

- Joint angular displacement was plotted between one segment, relative to another about the joint shared in common. The motion was reported in the polar coordinate system as a relative angular component about the pole (joint) as viewed along the XY, XZ, YZ planes.

- The magnitude of the X,Y,Z joint reaction forces were calculated from the kinematics with reference to the Cartesian reference coordinate system selected by the control points. The joint reaction forces in the X (horizontal),Y (vertical), and Z (lateral) directions were determined from a link-segment model.

- Net muscle moments, acting at each segment, were determined from the angular acceleration, reaction forces, and moment of inertia values obtained using the link-segment model.

Qualitative muscle identification for each movement was conducted to match the critical tasks and suggested strength requirements. Each critical task was further divided into specific critical points in the movement for muscular analysis.

4. Development of Criterion Tasks (CT):

A device is being designed and built which will duplicate the identified critical aircraft tasks (CT). Every effort will be made to ensure the device duplicates the actual cockpit parameters which can affect actuation of controls (e.g. seat travel, rudder pedal movement, stick height). The simulator will be a generic cockpit which will combine features of jet, propeller, and helicopter aircraft.

SEQUENTIAL BREAKDOWN - PHASE II

1. Development of Strength Data-base

Using the same muscle groups that actuate aircraft controls, we tested a representative sample of the current aviation candidate population to develop a strength data-base. This data will provide a better idea of the capabilities of the current population as well as allow a first time look at gender differences in strength for the Navy aviation candidate population. Anthropometric data were collected on each subject to assist in strength data analysis.

2. Development of Strength Test Battery (STB)

A strength test battery (STB) will be designed using muscle groups required to perform individual criterion tasks (CT). This STB will predict success in passing CTs and ultimately predict success in performing actual aircraft duties. The STB incorporates exercises and weight lifting regimes that can be performed at remote sites. Once the screening tool and STB are designed data will be collected on criterion tasks (CT) and STB.

3. Test Subjects on STB and CT

A database will be devloped on subject ability to perform CT's and the STB.

4. Analyze and Compare STB and CT Data

Relationships between STB and CT will be determined.

5. Cross Validate CT and STB

Confirmation of STB as predictor of successful CT performance will be accomplished.

6. Final STB

A final STB, which will adequately predict CT performance, will be established.

Guidelines will be provided in the form of Navy instruction to CNET/CNATRA/NASC.

SEQUENTIAL BREAKDOWN - PHASE III

1. Development of Physical Training Program to meet STB Requirements

   A remedial physical conditioning program will be developed for Naval Academy, ROTC, and Officer Candidate School graduates selected for naval aviation. The program will be designed specifically to improve strength in muscle groups used in accomplishing critical aircraft tasks (CT). The program will build on the training regime and equipment already in place at NASC. The remedial program will consist of a series of exercises selected to enhance the functional capability of particular muscle groups to better perform aviation related occupational tasks. The most important occupational tasks requiring muscular exertion and their specific maximal forces have been identified. A study of the movements of these tasks will reveal the anatomical parts of the body involved with each movement. From the motion analysis and force determination information, we will determine the best exercise routine to enhance the strength and endurance of those muscles. Extensive testing will be done to validate the program. The remedial program will include both calisthenics and exercises that can be performed with strength training equipment usually found at naval bases or onboard ships. Specifics into the correct performance of each exercise to include the frequency, duration, and intensity will be detailed in the program. If followed correctly, aviators found deficient in strength in any area identified by the screening device will be able to improve their strength and endurance within a reasonable period of time and maintain a level of muscular proficiency throughout their career. The benefits from such a program include increased inflight safety, enhanced aviation task performance critical to mission accomplishment, and improved health.

2. Final Report

   A technical report will be written and distributed.

3. Recommendation

   Recommendations for follow-on studies, and data transfer to other research projects will be made.

RESULTS

During this reporting period research was begun on Phases I and II of the project. Results are summarized for each segment.

PHASE I:

1. Background/Literature review

   A selected bibliography (Appendix (a)) was published reflecting the review of literature for the project. This bibliography reflects 134 selected publications from a variety of sources relating to gender related strength differences. The cited publications cover the time period from 1972 through October 1994. The literature search was conducted using the following databases: Defense Technical Information Center (DTIC), Medline, and PsychLit. The abstracts included are in original form. An index organized by subject matter was provided.

   Two articles were published in the Journal of the Safety and Flight Equipment (SAFE) association's, January 1995 issue. The articles were:

Development of Gender-Neutral Occupational Standards
I. Physical Training Issues. (Appendix (b))

Development of Gender-Neutral Occupational Standards
II. Job Demands and Physiological Issues. (Appendix (c))

2. Fleet-Wide Survey

A survey was sent to 43 aircraft model managers, or fleet replacement squadrons (FRSs) soliciting input on strength critical tasks involved in flying their particular aircraft. The survey asked to examine all physical tasks required to fly every mission associated with their particular aircraft. Task-specific performance, based on "worst case scenarios" for muscular strength and endurance in normal and emergency flight situations was to be evaluated. We requested a list of the top 5-10 strength or endurance critical tasks for each aircraft and a brief description of actions needed to perform these tasks. A response was received from all survey recipients, however nine aircraft were found to be out of the fleet inventory or going out within the year.

3. Field Visits/Motion Analysis

Critical tasks analyzed for motion analysis were selected based on results from surveying aircraft model managers. Motion analysis was accomplished for generic cockpit tasks instead of analyzing the same task in each aircraft. The cockpits/simulators used were selected based on availability to researchers. The critical tasks identified and the specific cockpits/simulators used were as follows:

a. ejection seat (LS1 & NACES)

b. manual landing gear (T-34)

c. canopy (T-34)

d. rudder pedals, stick: forward, back, left, right (T-2 simulator)

e. collective, rudder pedals, stick (TH-57)

f. wheel: aileron, elevator (C-130: Blue Angels "Fat Albert")

All data collection of each task within each aircraft has been completed. The digitizing, transformation and smoothing has also been completed on all tasks with the exception of the stick movements in the T-2 and the wheel movements in the C-130.

Appendix (f) is a draft scientific conference presentation for T-34 canopy and manual landing gear crank (to be submitted to S.A.F.E. annual symposium - August 18). Reports for other critical tasks analyzed are being prepared.

4. Measurements

The critical tasks provided an objective list of strength related tasks. An exact determination of the force required for each critical tasks was needed. Due to availability of the documentation, airframes, and expertise in force measurements, this area was subcontracted to personnel at Naval Air Warfare Center (Aircraft Division) Patuxent River, Maryland and Naval Air Systems Command, Arlington, Virginia. A list of the critical tasks was provided to these commands to obtain the actual force required for specific tasks by actually measuring the force or by obtaining the force data by searching the appropriate documentation. In the funding provided, a

METRECOM (portable three-dimensional measuring machine) was purchased by Naval Air Warfare Center, Patuxent River to assist and expedite the completion of the force data. The completed force data were initially promised by December, 1994. Force data suitable for establishing the screening tool force criteria were not obtained until July, 1995 resulting in a delay in construction of the screening tool. Since receiving the force data from the subcontractors, the model managers have been asked to review the data for their specific airframe.

5. Development of Criterion Tasks

Design and building of the screening tool was subcontracted to the Ergonomics Lab, Armstrong Laboratory (AL/CFHD), Wight-Patterson Air Force Base. The screening tool will need to provide a generic "cockpit-like" environment capable of measuring the force for the following critical tasks:

a) Stick aileron/elevator

b) Wheel aileron/elevator

c) Collective

d) Rudder Pedals

c) Center-pull ejection handle

f) Face-curtain ejection handle

g) Emergency Landing Gear Crank

To incorporate the hardware for measurement of all of the tasks in a single screening tools, reconfiguration for the stick and wheel must occur. Design of the screening tool will be such that this can be accomplished without tools and in less than one minute.

The stick, wheel, pedals, and center pull ejection handle will measure force through a specific range of motion which will simulate that found in a specific aircraft. In addition to measuring the force exerted through the range of motion, a maximum force will be measured at the end of the range. Strength endurance tests will be run on those controls identified as having endurance related critical tasks.

The face-curtain ejection handle will be a static (isometric) pull measuring the maximum strength exerted. The manual landing gear crank for the T-34C was identified as a critical task. Although this task is specific to the T-34C, this airframe is used as a trainer and the manual lowering of the landing gear is a requirement for completion.

PHASE II:

Development of strength database

Results presented do not include data collection efforts at NAS Whiting Field and the US Naval Academy in August and September, 1995. These trips were designed to increase the female sample size and provide a better analysis of data.

Four hundred twenty-six student naval aviators and student naval flight officers (average age 24 years) have been tested on the strength and endurance battery and anthropometric measurement series. Of this group, thirty-one were female, or 7.3% of the student population. This is characteristic of the female-to-male ratio in naval aviation. Muscular strength and endurance was measured with the Cybex 6000 Muscle Testing Device. Three major muscle groups were chosen for testing because of their involvement in performing most of the critical occupational tasks in aviation requiring muscular control. Using the Cybex, the muscle groups tested for strength and endurance were: the large muscles of the upper leg that extend and flex the knee (quadriceps and hamstrings), the muscles acting on the shoulder joint to cause rotation, and the elbow extensors and flexors (biceps and triceps).

The Cybex was configured to measure isokinetic concentric/concentric muscular force. For strength, the speed of movement was set at 60°/sec and 3-4 maximal exertion repetitions were performed. Following each strength set and a short rest period, a set of 20 maximal exertion repetitions at 180-240°/sec was accomplished for endurance. Only the right side of the body was tested to reduce the time of participation and maintain uniformity. Grip strength of both hands was measured with a hand grip dynamometer. The best of three trials was recorded. All of the subjects were given verbal encouragement by the operators during the strength tests.

Fifteen body dimensions were included in the anthropometric analysis. Fourteen of these particular dimensions were selected because of their importance in ensuring proper cockpit fit for performing flight-related tasks. The anthropometric variables measured were: weight, stature, thumbtip reach, bideltoid breadth, sitting height, sitting eye height, sitting acromial height, abdominal extension depth, sitting hip breadth, thigh circumference, thigh clearance, buttock-knee length, sitting knee height, functional leg length, and body fat estimation. The sum of three skinfolds was used to determine body composition. This variable was used to better assess strength by relating those variables to lean body mass.

Descriptive statistics were determined on all variables. Means and standard deviations for strength and endurance data are shown in Tables 1 and 2 and the anthropometric data in Table 3. Both gender groups and the total sample statistics are given along with the difference between the means of the males and females with statistical significance set at $P < 0.05$. In Tables 1 and 2, strength and endurance variables are separated and shown for each muscle group broken down further by the particular movement, i.e., flexion or extension. The different variables listed are defined in Appendix (g), while the definitions of the anthropometic measurements are given in Appendix (h).

Upon the completion of data collection, further statistical evaluation will be undertaken using the entire set of strength and anthropometric data. Correlational analysis will be done to determine collinearity or the amount of variance accounted for by each variable in the model. Discriminant analysis will be used to identify the most important variables in defining the disproportionality between males and females. And finally, multiple regression analysis will be accomplished to show how certain variables relate to other variables that are known to be important in performing aviation occupational tasks.

Table 1. Means ($\bar{x}$) and Standard Deviations (SD) of Strength Variables

Variables	Male, n=395 $\bar{x}$	SD	Female, n=31 $\bar{x}$	SD	X Difference t-value
Knee					
Flexion					
Peak Torque (ft-lbs)	100.23	17.64	65.71	12.15	10.71*
TAE (ft-lbs)	7.60	1.79	4.65	1.16	9.03*
Extension					
Peak Torque (ft-lbs)	171.94	29.85	115.07	21.08	10.40*
TAE (ft-lbs)	11.74	2.58	6.91	1.31	10.30*
Elbow					
Flexion					
Peak Torque (ft-lbs)	41.12	7.77	23.58	4.91	12.36*
TAE (ft-lbs)	2.48	0.85	1.19	0.50	8.35*
Extension					
Peak Torque (ft-lbs)	44.22	9.12	29.23	6.67	8.97*
TAE (ft-lbs)	3.60	0.76	1.99	0.42	11.70*
Shoulder					
Flexion					
Peak Torque (ft-lbs)	25.87	5.70	15.23	3.22	10.27*
TAE (ft-lbs)	2.65	0.61	1.43	0.35	10.94*
Extension					
Peak Torque (ft-lbs)	42.76	8.79	25.07	6.09	10.99*
TAE (ft-lbs)	3.82	0.97	2.08	0.61	9.85*
Grip Strength					
Right (kg)	52.01	6.96	36.39	5.19	11.63*
Left (kg)	49.57	6.87	34.01	5.13	11.32*

Table 2. Means ($\bar{x}$) and Standard Deviations (SD) of Endurance Variables

Variables	Male n-395 $\bar{x}$	SD	Female n=31 $\bar{x}$	SD	X Difference t-value
Knee					
Flexion					
Total Work (ft-lbs)	80.63	16.17	53.84	11.89	9.03*
Ave Power (W)	203.44	41.23	139.94	31.51	8.38*
Extension					
Total Work (ft-lbs)	122.75	22.70	80.23	16.97	10.20*
Ave Power (W)	303.22	65.04	201.65	41.28	8.56*
Elbow					
Flexion					
Total Work (ft-lbs)	38.99	9.38	20.90	7.12	10.50*
Ave Power (W)	90.68	24.08	44.23	19.14	10.48*
Extension					
Total Work (ft-lbs)	47.60	8.99	28.58	7.49	11.46*
Ave Power (W)	109.28	22.75	62.61	18.22	11.14*
Shoulder					
Flexion					
Total Work (ft-lbs)	24.92	6.49	14.16	4.15	9.07*
Ave Power (W)	59.96	14.47	29.00	8.91	9.08*
Extension					
Total Work (ft-lbs)	48.09	9.57	31.10	6.13	9.72*
Ave Power (W)	101.16	22.91	63.03	13.66	9.13*

Table 3. Means ($\bar{x}$) and Standard Deviations (SD) of Anthropometric Variables

Variables	Male n=35 $\bar{x}$	Male n=35 SD	Female n=31 $\bar{x}$	Female n=31 SD	X Difference t-value	Total n=426 $\bar{x}$	Total n=426 SD
Weight	79.33	9.49	65.51	8.28	7.87*	78.32	10.06
Stature	179.51	6.40	167.65	5.17	10.07*	178.65	7.03
Thumbtip Reach	82.87	4.14	77.67	2.96	4.76*	82.47	4.28
Bideltoid Breadth	49.60	2.73	44.21	2.39	10.66*	49.20	3.04
Abdominal Extension Depth	23.26	3.36	21.66	5.84	2.39*	23.14	3.61
Hip Breadth, Sitting	35.78	3.40	37.09	5.06	-1.98*	35.88	3.56
Height, Sitting	93.17	3.54	87.83	2.84	8.21*	92.78	3.75
Eye Height, Sitting	80.99	3.26	76.37	2.81	7.66*	80.66	3.45
Acromial Height, Sitting	60.68	3.16	57.38	2.60	5.66*	60.44	3.24
Thigh Circumference	59.79	4.34	59.67	3.80	0.15	59.79	4.30
Thigh Clearance	17.31	1.19	15.83	1.28	6.52*	17.21	1.26
Buttock-Knee Length	62.55	2.87	59.07	2.68	6.42*	62.30	2.99
Knee Height, Sitting	55.91	2.57	51.81	3.05	8.32*	55.62	2.81
Functional Leg Length	109.99	5.20	103.10	4.24	7.07*	109.51	5.43

* $P < 0.05$
All measures are in centimeters except weight which is kilograms.

CONCLUSIONS

At the end of this reporting period the project has met most of its accelerated milestones. The literature review was completed and published as a selected bibliography. Two articles were published on the subject in the Journal of the Safety and Flight Equipment (SAFE) association. A fleet-wide survey was completed for all current naval aircraft which provided a basis for what critical aircraft tasks need to be screened for. Motion analysis of these tasks has begun and reports for each task grouping are in various stages of production. Force data were collected for each critical task via historical aircraft engineering reports. Data collection in this area is complete but was finished three months after its projected accelerated milestone. This delay has also effected milestone completion of design/construction of strength screening tool. The screening tool design and construction has begun and construction is anticipated to be complete (pending FY-96 continuation funding) by 1 January, 1996. A strength data-base has been started by testing 426 incoming pilot/NFO students for 3 main muscle groups and 15 anthropometric measurements. Data collection in this area will continue and an over sampling of the female population will be done to assure appropriate data analysis can be completed.

This project was accelerated by obtaining funds from Defense Women's Health Research Project (DWHRP) funding. The project has been accelerated as much as time and personnel constraints allow. Funding received thus far has accelerated milestone by 12 months. We hope to receive DWHRP continuation funds to attempt to complete the project in FY 96. Current plans for FY 96 include completion of screening device and initiation of validation testing of the device. Once a representative sample of aviator and potential aviators have been tested on the device a report will be made to the Bureau of Naval Personnel for guidance on fielding the device at the Naval Aviation Schools Command. Work on Phase II of the project has begun with the strength database and the motion analysis of the tasks. Work in FY 96 for Phase II will complete the strength data base and will begin analysis and validation of the screening tool and the strength test battery to be used at remote sites. It is anticipated that work will also begin on the remedial physical conditioning program of Phase III. Actual project completion date and next year's milestones will depend on funding received for next fiscal year.

The data collected thus far have demonstrated the need for this type of research project. The significant strength differences seen between males and females in the aviation candidate population suggest a definite need for this program. The researchers believe this type of program can be applied to other areas of military duties to ensure a compatible match of personnel to tasks. Other anticipated by-products of this type of research are proposed engineering changes to improve safety in task completion. This lab has proposed future studies to examine tasks of enlisted aircrew and flight deck personnel on aircraft carriers.

FUTURE CONCERNS

Preliminary results and previous studies suggest a definite need for this project. The initial study was designed to be accomplished in a four year period of time. Acceleration funding received in FY95 has allowed one-third project completion in ten months. Funding guidance received thus far for FY96 will allow project to proceed for only approximately three months (Appendix (i)). Without DWHRP continuation funding work on this important project will stop in December 1995, before any of the Phases are complete. This will mean all efforts made thus far will be wasted. Stoppage will not allow for validation of screening device or completion of strength test battery.

A budget (Appendix (j)) has been submitted which will allow project completion in FY96. If this funding is received, the project will have been completed two years ahead of schedule for the same amount originally budgeted. The total cost of this study ($1.9 million) is but a fraction of the cost savings realized if just one aircraft and/or life is saved by selection standards instituted (e.g., $30 million aircraft). The biggest concerns we have now is that research efforts thus far will be lost, and this important concern will not be addressed. The consequent of not proceeding may be lost lives and lost aircraft.

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Naval Aerospace Medical Research Laboratory

NAMRL Monograph 47

OCCUPATIONAL STRENGTH TESTING RELATED TO GENDER-NEUTRAL ISSUES IN NAVAL AVIATION: A SELECTED BIBLIOGRAPHY

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Appendix (a)

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ABSTRACT

This bibliography presents the results of a literature review to provide background information for the study "Performance-based Occupational Strength Testing for Candidate Navy Pilots/Naval Flight Officers." The purpose of this work is to develop an occupational strength test battery to establish gender-neutral standards in naval aviation selection. This research, partially funded by the Defense Women's Health Research Program, was prompted by a congressional decision to allow smaller statured individuals entry into military aviation. The long-range objective of this project is to test and identify individuals capable of meeting specific strength requirements to safely operate naval aircraft. The cited publications cover the time period from 1972 through October 1994. The literature search was conducted using the following databases: Defense Technical Information Center (DTIC), Medline, and PsychLit. The abstracts included in this bibliography are in original form. An index organized by subject matter is provided.

1. **AGARD.**
Recruiting, selection, training and military operations of female aircrew.
Neuilly Sur Seine, France, 1990, Advisory Group for Aerospace Research and Development, AGARD-CP-491.

In recent years a number of the NATO nations have begun to select female aviators for roles which have been traditionally reserved for males. New aviator roles for females include flying high performance ejection seat aircraft and helicopters, including combat missions. A number of physiological and ergonomic considerations are raised. These include design specifications (i.e. physical dimensions) of aircraft cockpits and personal life support equipment, as well as factors such as physiological aptitudes for certain types of flying (e.g. high G). New categories of medical decisions making (e.g. flying during pregnancy) are being formulated. This Symposium was designed to share the experience to date among NATO nations and to indicate where further research/design improvement was most urgently required.

2. **Aghazadeh, F.; Ayoub, M. M.**
"A comparison of dynamic- and static-strength models for prediction of lifting capacity."
Ergonomics. 28(10): 1409-1417. 1985.

An experiment was designed and conducted for the development, testing and comparison of models for prediction of weight lifting capacity of individuals incorporating static and dynamic strengths. The dependent variable was the maximum acceptable amount of lift and the independent variables were static strengths, and dynamic strengths of the individual in a simulated lifting position and task variables--height and frequency of lift. Data from nine male subjects were used for analysis. It was concluded that both the dynamic and static models developed in the study can predict the maximum acceptable amount of lift with a reasonable degree of accuracy. However, comparison of the models revealed that the use of the dynamic model with one operator variable resulted in less absolute error between the actual and predicted load than the static model. This study, which is based on the data from a limited number of subjects, indicates that the dynamic approach may be superior to the static approach.

3. **Andersson, R.; Lagerlof, E.**
"Accident data in the new Swedish information system on occupational injuries."
Ergonomics. 26(1): 33-42. 1983.

To improve work environment there is a need for knowledge about risks. One must identify the risks, evaluate them and find their antecedents. As an aid in this work the Information System on Occupational Accidents and Diseases (ISA) has been built up at the National Board of Occupational Safety and Health. ISA is based on claims for work injury insurance. Every accident is classified according to the injured person's occupation, branch and activity. The accident is described as a sequence of events. The agencies involved, i.e. machines, tools, materials that influenced each stage of the antecedent, are also described. For statistical purposes one main event and one main agency per accident are selected by computer programs. Each variable is accessible through the computer register. Thus it is possible, apart from official statistics, to produce individual extracts based on very specific needs. For falling, tripping and slipping accidents the following information is obtainable: distribution by branch or occupation, the different sequences of events for falling, slipping or tripping, the severity of injuries, etc.

4. **Arciero, P. J.; Goran, M. I.; Poehlman, E. T.**
"Resting metabolic rate is lower in women than in men."
Journal of Applied Physiology. 75(6): 2514-2520. 1993.

This study examined gender differences in resting metabolic rate (RMR) across a broad age spectrum after controlling for differences in body composition and aerobic fitness. Three hundred twenty-eight healthy men (17-80 yr) and 194 women (18-81 yr) volunteers were characterized for RMR, body composition, physical activity, peak oxygen consumption (peak VO2), anthropometrics, and energy intake. Measured RMR was 23% higher ($P < 0.01$) in men (1,740 $\pm$ 194 kcal/day) than in women (1,348 $\pm$ 125 kcal/day). Multiple regression analysis showed that 84% of individual variation in RMR was explained by fat-free mass, fat mass, peak VO2, and gender. After controlling for differences in fat-free mass, fat mass, and peak VO2, a lower RMR (3%; $P < 0.01$) persisted in women (1,563 $\pm$ 153 kcal/day) compared with men (1,613 $\pm$ 127 kcal/day). Adjusted RMR in pre menopausal ($P < 0.01$) and post menopausal ($P < 0.05$) women was lower than in men of a similar age. Our results support a lower RMR in women than in men that is independent of differences in body composition and aerobic fitness.

5. **Armstrong, D. S.; Berkman, B.; Floren, T. M.; Willing, L. F.**
A handbook on women in fire fighting: The changing face of the fire service.
Federal Emergency Management Agency, United States Fire Administration, Women in the Fire Service, Madison, WI, 1992.

6. **Arnold, J. D.; Rauschenberger, J. M.; Soubel, W. G.; Guion, R. M.**
"Validation and utility of a strength test for selecting steelworkers."
Journal of Applied Psychology. 67(5): 588-604. 1982.

The lack of adequate performance criteria necessitated the use of a combined content- and construct-referenced strategy to identify valid selectors for filling steel working positions on the basis of physical ability. First, work samples (WSs) of entry-level positions were formed for each of three sites. Potential selectors were then chosen, and 168 men and 81 women at the three sites (comprising mostly steelworkers in the first 6 months of employment) performed both the selection and WS tasks. A measure of static strength, the arm dynamometer, was found to have especially strong correlations with WS performance; the average correlation with the three composite measures of performance was 0.84. Multiple regression analyses revealed no advantage in using more than the arm dynamometer for selection, and bias analyses showed that the measure would have, at most, a slight adverse impact against males. Using conservative estimates, it was determined that using the arm dynamometer as a selector could potentially save the company over $9 million a year.

7. **Aume, N. M.**
A machine for weight-lift testing.
Air Force Aerospace Medical Research Lab, Wright-Patterson AFB, OH, 1984, AFAMRL#TR-84-040.

This report describes the design and building details of a weight-lifting machine which is primarily intended for Factor X testing where only occasional use is foreseen and an expensive machine would not be cost effective. The machine allows the weight to move only up and down, eliminating any unwanted and hazardous motions.

8. **Aume, N. M.; McDaniel, J. W.; Garver, T.**
Human strength capabilities for the operation of parachute ripcords and riser releases.
Air Force Aerospace Medical Research Lab, Wright-Patterson AFB, OH, 1983, 60 pp., DTIC#AD-A138 328.

Military Specification MIL-P-6645H permits a maximum pull of 27 pounds to activate a parachute ripcord. A test was conducted to evaluate this force. Two hundred eleven physically fit male and female subjects made maximum voluntary exertions on five different parachute ripcord handles with the left hand, the right hand, and with both hands. The applied isometric forces were recorded. Considerable differences in the recorded forces were found to be attributable to sex and to one versus two hand pulls; lesser differences were caused by variations in the ripcord handle types and locations. When both hands were used, almost all male subjects could exceed the permitted 27-pound pull. Significant numbers of female subjects using either one or both hands, and male subjects using only one hand could not exceed 27 pounds of pull. As a result, the authors recommend that the currently specified 27-pound limit not be increased as has been proposed, and that teaching the two-hand pull be continued. The same subjects also performed maximum voluntary exertions on two types of riser releases with the left and right hands. The type of riser release caused a significant difference in the force exerted.

9. **Avellini, B. A.; Kamon, E.; Krajewski, J. T.**
"Physiological responses of physically fit men and women to acclimation to humid heat."
Journal of Applied Physiology. 49(2): 254-261. 1980.

Four men and four women with comparable maximal aerobic capabilities and equal surface areas and surface area-to-mass ratios underwent a 3 hour heat stress test before and after a 10-day acclimation to humid heat. Women were tested during both pre- and post-ovulation. Prior to acclimation, pre-OV women exhibited the longest tolerance times and lowest rectal temperatures (Tre) and heart rates (HR) throughout testing. Men secreted considerably more sweat per unit area than did women in either phase of the cycle, yet they demonstrated shorter tolerance times and higher body temperatures and HR. During post-OV, women reacted similarly to men except that their sweat rates and HR values were significantly lower. Following acclimation, the Tre and HR of the men and women were similar, whereas the discrepancy between the sweat rates was magnified. It was concluded that aerobic capacity is an important factor to be considered when men and women are compared in the heat. When fitness levels are similar, the previously reported sex-related differences in response to an acute heat exposure seem to disappear, except for the higher sweat rate for men.

10. **Avellini, B. A.; Shapiro, Y.; Pandolf, K. B.; Pimental, N. A.; Goldman, R. F.**
"Physiological responses of men and women to prolonged dry heat exposure."
Aviation, Space and Environmental Medicine. 51(10): 1081-1085. 1980.

Heat-acclimated men (n = 10) and women (n = 9) were exposed to hot-dry conditions (49 degrees C, 20% rh) for 4h to determine the effect of prolonged work in the heat on physiological differences between the sexes. Hourly exposures consisted of 10 min resting and 50 min walking at 1.34 m/s (time-weighted metabolic rate = 175 and 151 W/m^2 for men and women, respectively). No significant difference in rectal temperature (Tre) was found between the sexes for each hour (h) of exposure. Heart rate (HR) of women, however, averaged 10-17 beats/min higher than men. Mean skin temperature (Tsk) was also significantly higher in women throughout the exposure. For both sexes, the 4th-h Tre, HR, and Tsk were significantly higher than the preceding 3h. No sex related differences in total sweat rate (msw) or sweat sensitivity, as indicated by msw/delta Tre, were evident. It was concluded that: a) prolonged exposure to dry heat does not accentuate physiological differences between the sexes; b) women sweat at rates comparable to men over a 4-h period; c) 2-h acclimation sessions do not necessarily acclimate individuals for work of longer duration.

11. **Baisden, A. G.**
Gender and performance in naval aviation training.
Naval Aerospace Medical Institute, Pensacola, FL, 1992, 4 pp., DTIC#AD-P006 957.

Women have played an important role in naval aviation since their entry into naval aviation training as pilots in 1973 and as naval flight officers in 1979. Heightened by the Congressional debates over women in combat, questions are being raised regarding equitable selection, fair treatment in training, and equality of opportunity. This paper presents a brief historical perspective of the rationale and research related to women in military aviation, examines selection and training data of 13,755 men and 421 women who entered naval aviation training from 1984 to 1991, and addresses the issues of equitable selection and fairness in naval aviation training. Analyses of the data include descriptive statistics and t-tests to compare male/female performance on selection tests and preflight training grades, a test of equal proportions and a chi-square test to assess differences in attrition, correlation and regression analyses to determine the significance of relationships between selection test measures and performance in preflight training. Analysis of gender differences indicated that women had significantly better scores than men on the aviation selection tests which are predictive of preflight academic training performance ($p < 0.01$). Their performance grades during the preflight academic training, however, were significantly lower than that of men ($p < 0.01$). Attrition rates and types of attrition did not differ. Implications of the findings and future directions for research are suggested.

12. **Baldi, K. A.**
"An overview of physical fitness of female cadets at the military academies."
Military Medicine. 156(10): 537-539. 1991.

13. **Balldin, U. I.; Myhre, K.; Tesch, P. A.; Wilhelmsen, U.; Andersen, H. T.**
"Isometric abdominal muscle training and G tolerance."
Aviation, Space and Environmental Medicine. 56(2): 120-124. 1985.

Methods to increase G tolerance of pilots flying high-performance aircraft are of vital importance. Straining maneuvers to increase G tolerance involve abdominal muscles, and high intra-abdominal pressures (IAP) are recorded during G exposure. This study was carried out to examine the effects of an 11-week abdominal muscle training program on maximal IAP, G tolerance and muscle strength/endurance in 10 fighter pilots. G tolerance was measured in a human centrifuge using simulated aerial combat maneuvers (ACM). The pilots had a higher maximal IAP before training than a control group. G tolerance, maximal IAP, and maximal peak torque of knee extensors were not changed by the training. In contrast, leg muscle endurance increased ($p < 0.01$) and ratings of local perceived exertion decreased ($p < 0.01$). Static endurance of the knee extensors was positively correlated ($p < 0.05$) with G tolerance. It is concluded that the present abdominal training program, employed in experienced fighter pilots, is not sufficient to increase IAP or G tolerance.

14. **Barnes, W. S.; Hasson, S. M.; Gadberry, W. L.; Henrich, T. W.; Fang, C. L.**
"Absolute and relative power output in men and women."
Perceptual and Motor Skills. 63(3): 1309-1310. 1986.

Measurements of 18 men and 19 women in physical activity courses show men generate more absolute muscle power than women and produce greater power per unit of time. If absolute power does not accurately reflect the power/weight ratio, it may not be a reliable predictor of certain athletic performance.

15. **Bensel, C. K.; Fink, D. S.; Mellian, S. A.**
The psychomotor performance of men and women wearing two types of body armor.
Army Research and Development Command, Natick, MA, 1980, 117 pp., DTIC#AD-A086 742.

This study was conducted to determine the effects of load-carrying equipment (LCE) and two types of fragmentation protective armor vests, Standard B Fragmentation protective armor vests, Standard B Fragmentation Protective Body Armor (STD B) and the Personnel Armor System for Ground Troops (PASGT), on body flexibility, rate of movement, psychomotor coordination, manual dexterity, and effort exerted for task performance. Twelve men and twelve women, outfitted in utilities, performed the battery of 16 tasks under each of the following clothing conditions: utilities alone, STD B armor, PASGT armor, LCE, STD B armor +LCE, and PASGT armor + LCE. In general, performance levels were highest when the utilities were worn without any additional items and lowest when the STD B vest was worn in conjunction with the LCE. The STD B armor impaired certain aspects of psychomotor performance, particularly body flexibility, to greater extent than the PASGT vest did. The collar and shoulder designs seemed to be the critical features responsible for the superior performance achieved with the PASGT vest. After the data had been transformed to remove effects accounted for by difference in the basic capabilities of men and women, two tasks which required arm movements were found to be significantly affected by the sex variable. The women's performance of these movements was impaired relative to the men's because of the excessive length of the armor across the women's shoulders.

16. **Bielenda, C. C.; Knapik, J.; Wright, D. A.**
"Physical fitness and cardiovascular disease risk factors of female senior U.S. military officers and federal employees."
Military Medicine. 158(3): 177-181. 1993.

This study compared physical fitness and cardiovascular risk factors between military officers (N = 23) and civilians (N = 17). Subjects were women (average age 43 years) who attended the U.S. Army War College from 1986-1991. Officers had less body fat, higher aerobic capacity, lower resting heart rates, lower resting diastolic blood pressure, higher HDL, and marginally lower triglycerides. Female military officers appear to be more fit and have lower cardiovascular risk factors than their civilian counterparts.

17. **Billingsley, P. A.; Hudgens, G. A.**
Human performance: Sex differences and the influence of the menstrual cycle (A selected bibliography).
Human Engineering Lab, Aberdeen Proving Ground, MD, 1978, 71 pp., DTIC#AD-A056 799.

This bibliography is a compilation of 640 references dealing with, or related to, the effects of sex differences and the menstrual cycle on human performance. The material is organized into six categories: An Overview of Sex Differences, Physiological Sex Differences, Sex Differences in Cognitive and Motor Skills, Sex Differences in Personality, Women in Non-Traditional Occupations, and Psychophysiology of the Menstrual Cycle. An index of first authors is included. The time period covered is roughly from the 1930's through mid-1977.

18. **Braith, R. W.; Graves, J. E.; Leggett, S. H.; Pollock, M. L.**
"Effect of training on the relationship between maximal and sub maximal strength."
Medicine and Science in Sports and Exercise. 25(1): 132-138. 1993.

The purpose of this study was to evaluate the validity of a dynamic seven to 10 repetition maximum (7-10 RM) test to estimate maximal knee extension strength (1-RM) in untrained and trained subjects. Thirty-three men and 25 women (25 $\pm$ 5 yr) were randomly assigned to a group that trained two or three times/wk for 18 wk (N = 47) or a control group (N = 11). Training included one set of 7-10 repetitions to volitional fatigue on a Nautilus knee extension machine. Prior to (T1) and after training (T2) dynamic strength was evaluated by 1-RM and 7-10 RM tests. The 7-10 RM test consisted of one set of variable resistance knee extension exercise performed to volitional fatigue with a weight that allowed 7-10 repetitions. The training group improved their 1-RM and 7-10 RM strength (by 31.7 and 51.4%, respectively) ($P \leq 0.01$) while the control group did not change. Training increased relative 7-10 RM strength (68.4% of 1-RM at T1 and 79.1% of 1-RM at T2) ($P \leq 0.01$). The relationship between the 7-10 RM weight and 1-RM at T1 was linear: 1-RM = 1.554 (7-10 RM weight)-5.181; R2 = 0.89; SEE = 9.3 kg. Application of this equation following training resulted in a systematic overprediction ($p \leq 0.01$) of 1-RM (21.2 kg) in trained subjects. Therefore, a second linear equation was developed to predict 1-RM in trained subjects: 1-RM=1.172(7-10 RM weight)+7.704; R2=0.91; SEE=9.9 kg. Our results indicate that a test consisting of 7-10 repetitions performed to exhaustion can accurately predict 1-TM knee extension strength. However, resistance training alters the relationship between maximal and sub maximal strength, and thus the level of training is an important consideration when estimating 1-RM strength from a multiple repetition test performed to volitional fatigue.

19. **Brown, C. H.; Wilmore, J. H.**
"The effects of maximal resistance training on the strength and body composition of women athletes."
Medicine and Science in Sports. 6(3): 174-177. 1974.

Strength, body composition, and anthropometric measurements were made on seven women throwing event athletes before and after three and six months of training. Strength was determined by one-repetition maximum in the bench press and half-squat, and body composition was assessed by densitometry. In five of the subjects, strength training with near-maximal loads was carried out 3 days per week using dumbbells, barbells and a leg press apparatus. Additional training consisted of running, team sports, and technique drills. After 6 months, the 5 subjects who weight trained increased in bench press strength by 15 to 44 percent and in the half-squat by 16 to 53 percent; the two subjects who did not weight train showed little or no strength gain. Lean body weight increased only in the largest subject and in the two who did not strength train while adipose tissue decreased in the 3 "average" and 2 "obese" subjects but rose in the two leanest. Upper extremity girths increased slightly in all, regardless of strength training, but thigh girth was essentially unchanged. Hence, women are capable of responding to strength training with considerable increases in strength and only minimal evidence of muscular hypertrophy.

20. **Brown, W. R.; Dohme, J. A.; Wicke, D. C.**
An evaluation of minority and female performance in Army Rotary Wing Aviation Training. Vol. II: Evaluation report.
Army Research Institute for the Behavioral and Social Sciences, Alexandria, VA, 1980, PERI-SR 1319.

This report contains the Executive Summary of the evaluation of minority and female performance in the Army's Initial Entry Rotary Wing flight training program. Each minority group was compared to a matched sample of majority students. The groups were matched on FAST score, GT score, educational level, age, rank, and source of entry. The performance of the two groups (each minority and its matched control group) was compared on the following criteria: (1) Warrant Officer Candidate Military Development Course grades; (2) Academic grades by phase of training; (3) Flight performance grades by phase of training; (4) Overall grade; (5) Attrition experience during the Warrant Officer Development Course and; (6) Attrition experience during the flight portion of training.

21. **Bullock, M. I.**
"The determination of functional arm reach boundaries for operation of manual controls."
Ergonomics. 17(3): 375-388. 1974.

In the planning of the manual workspace of automobiles and aircraft cockpits, it is important that the designer should have access to data which can illustrate the reach capabilities of the potential user population. This paper presents a method which has been developed for the collection of such data. The subjects used for measurement represented the male and female Australian pilot population in terms of height and, during the measurement procedure, they were firmly restrained by lap and sash harness while seated on an experimental chair with specifications similar to those found in current light aircraft. A description is given of the apparatus which allowed rapid recording of the measurements required for the determination of functional arm reach boundaries to an accuracy of $\pm$ 2 mm. The procedure which was followed while measuring maximum arm reach to 170 positions in space around each subject is outlined, together with the details which ensured experimental consistency throughout the project. Results are presented to define the boundaries reached by 95% of male and by 95% of female pilots and to indicate their accessibility to controls while firmly restrained with lap and sash harness in cockpits of some present light aircraft.

22. **Bullock, M. I.**
"Ripcord release capability of female parachutists."
Aviation, Space and Environmental Medicine. 49(10): 1177-1183. 1978.

With the growth in popularity of skydiving as a sport has come an associated increase in parachuting accidents, some of them due to failure to deploy the main or reserve parachutes. The absence of appropriate strength data has prompted a study of the pull force capabilities of female parachutists on a ripcord release in varying positions. Pull forces exerted for periods of 0.25, 1, 1.5, 2, and 2.5 second during a 5-second pull are presented in percentile form. A substantial percentage of female parachutists could not exert the maximum ripcord release pull force permitted by the relevant parachute specification. The relatively low level of strength exhibited by the weakest groups of the population emphasizes the need for such basic information in equipment design.

23. **Bunc, V.**
"A simple method for estimating aerobic fitness."
Ergonomics. 37(1): 159-165. 1994.

Physical activity is an integral part of everyday life. In order to evaluate physical fitness, there is a need for simple measures of which motor performance testing is one. The frequently used method for evaluating aerobic fitness, proposed by Cooper (1968), is based on measurements of an American population, and may involve estimating inaccuracy for aerobic fitness when used under European conditions. In this paper, tables for the estimation of aerobic fitness and physical performance are derived from a European sample (229 males, 153 females), incorporating general relations between velocity of movement and energy required for this activity expressed indirectly by oxygen consumption. The basic element of this evaluation under field conditions is the mean velocity of motion on a 2000 m track. The tables have been prepared for males and females aged 14-65 years, making it possible to estimate 'poor', 'good', and 'excellent' levels of aerobic fitness and physical performance. The error of assessment of maximal oxygen uptake and the physical fitness level varies by about 8%.

24. **Caldwell, L. S.; Chaffin, D. B.; Dukes Dobos, F. N.; Kroemer, K. H.; Laubach, L. L.; Snook, S. H.; Wasserman, D. E.**
"A proposed standard procedure for static muscle strength testing."
American Industrial Hygiene Association Journal. 35(4): 201-206. 1974.

25. **Campion, M. A.**
"Personnel selection for physically demanding jobs: Review and recommendations."
Personnel Psychology. 36(3): 527-550. 1983.

Improvement in personnel selection systems for physically demanding jobs is needed due to equal employment opportunity (EEO) considerations, concern for worker physical well-being, and the lack of alternative procedures. After addressing the special EEO sensitivities of physical abilities selection, the literature is reviewed from a variety of disciplines on (1) the physiological background underlying the selection strategies, (2) the assessment of human physical abilities, (3) the measurement of physical requirements of jobs, and (4) the physical abilities personnel selection studies reported in the literature. Conclusions are provided in the form of recommendations for future research.

26. **Canine, M. K.; Derion, T.; Heaney, J. H.; Pozos, R.**
An annotated bibliography of heat tolerance: Regarding gender differences.
Naval Health Research Center, San Diego, CA, 1994, 52 pp., DTIC#AD-A280 755.

The purpose of this technical report is to provide an overview of the literature on the similarities and differences between men and women in their physiological responses to heat stress. Studies that compare thermoregulation in physically fit and sedentary females, as well as research examining the effect of the menstrual cycle on thermal physiology, are included. For each study review, a brief synopsis of the methodology and a summary of relevant results are provided. It was the intent of this report to provide a literature resource, not a review paper, regarding gender differences in thermoregulation during heat exposure.

27. **Carretta, T. R.**
Gender differences in USAF pilot training performance.
Air Force Human Resources Lab, Brooks AFB, Texas, 1990, 20 pp., Proceedings of Twelfth Psychology in the DoD Symposium.

A recent study reported that male pilot candidates successfully complete Undergraduate Pilot Training (UPT) at a significantly higher rate than did female pilot candidates. Results from the study reported here suggest that most of the difference in UPT performance for male and female pilot candidates can be attributed to differences on pre-UPT performance indicators. When male and female pilot candidates are matched on level of pre-UPT performance composites, males and females commissioned through either ROTC or OTS perform equally well in UPT. Results for AFA pilot candidates were mixed. In some instances pre-UPT composites over predicted UPT performance for AFA females relative to AFA males. Implications for USAF pilot candidate selection procedures are discussed.

28. **Chaffin, D. B.**
"Ergonomics guide for the assessment of human static strength."
American Industrial Hygiene Association Journal. 36(7): 505-511. 1975.

29. **Chaffin, D. B.; Herrin, G. D.; Keyserling, W. M.**
"Pre employment strength testing: An updated position."
Journal of Occupational Medicine. 20(6): 403-408. 1978.

This investigation was conducted to evaluate the practicality and potential effectiveness of pre employment strength testing in reducing the incidence and severity of musculoskeletal and back problems in materials handling jobs. Prior to assignment to new jobs, 551 employees in six plants were given a series of strength tests and then monitored for approximately 18 months. During this time, all medical incidents were documented. An analysis of these incidents revealed that a worker's likelihood of sustaining a back injury or musculoskeletal illness increases when job lifting requirements approach or exceed the strength capability demonstrated by the individual on an isometric simulation of the job. Because strength was found to be weakly correlated with other individual attributes (e.g. gender, age, weight and stature), the authors conclude that industry should implement specific employee selection and placement programs using a strength performance criterion.

30. **Charles, M. T.**
"Women in policing: The physical aspect."
Journal of Police Science and Administration. 10(2): 194-205. 1982.

31. **Christ, C. B.; Boileau, R. A.; Slaughter, M. H.; Stillman, R. J.; Cameron, J.**
"The effect of test protocol instructions on the measurement of muscle function in adult women."
Journal of Orthopedic Sports Physical Therapy. 18(3): 502-510. 1993.

Consideration of the anatomy of the nervous system and events (i.e., age, physical training, motor learning) that invoke changes in neural regulatory mechanisms and other bodily systems renders the impact of the type of instruction used to elicit a maximal effort in the assessment of muscle function across age, among different muscle groups, and for different parameters of muscle function tenuous. Hence, the efficacy and effect of using two types of instructions (rate vs. strength) on the assessment of the isometric functional capacity of six muscle groups were examined in women (N = 143) aged 25-74 years. The subjects were categorized by age into 10, 5-year groups. Measures of maximal force (MF), maximal rate of force increase (MR), total impulse (TI), time to MF (MFT), time to MR (MRT), and plateau time (PLT, time between 90% MF and MF) were obtained from the force-time recordings of maximal voluntary isometric contractions of the finger flexors, thumb extensors, elbow flexors and extensors, and ankle dorsiflexors and plantar flexors. Repeated measures analyses of variance indicated that instruction type influenced ($p < 0.05$) the magnitude and pattern of the force-time recordings, with the degree of difference dependent upon the muscle group and parameter of muscle function examined. Use of the rate instruction yielded greater MRs (40.9-541.0 N/sec) than the strength instruction. The strength instruction elicited greater MFs (6.4-326.7 N), longer MFTs (0.72-1.50 sec), MRTs (0.05-0.15 sec) and PLTs (0.31-0.79 sec), and greater TIs (25.1-1,079.8 N-sec) than the rate instruction. An instruction that requires the subject to contract as fast as possible is recommended when rate parameters of muscle function are of interest; a test protocol that requests the subject to contract as hard as possible is recommended when the force parameters are assessed. Consideration of test protocol instruction is germane to obtaining accurate muscle function data. The use of two different instructions may provide more accurate and comprehensive muscle function data. The use of two different instructions may provide more accurate and comprehensive isometric muscle function data than the traditional use of a single instruction.

32. **Clauser, C. E.; McConville, J. T.; Gordon, C. C.; Tebbetts, I. O.**
Selection of dimensions for an anthropometric data base. Volume 2. Dimension evaluation sheets.
Anthropology Research Project Inc., Yellow Springs, OH, 1986, 420 pp., DTIC#AD-A179 472.

Anthropometric dimensions measured in 14 major foreign and domestic military surveys were reviewed in detail for possible inclusion in an anthropometric survey of U.S. Army men and women. Detailed review of each dimension included the following information: a description of the dimension, subject position, and landmarks required; type of instrument used; significant technique differences among surveys; alternative dimensions that could serve the same function in a data base; summary statistics from surveys that included the dimensions; notation of significant gender or racial differences for the dimension; ease of reproducibility, and factors contributing to reproducibility problems (if any); and a rating (with rationale) of the dimension's relative utility for a U.S. Army data base. Review sheets summarizing this information comprise Volume II of this report. Background information, discussion, and conclusions regarding those dimensions worthy of further consideration for inclusion in a U.S. Army anthropometric data base are presented in Volume I.

33. **Cote, R. W. III; Bomar, J. B. J.; Robertshaw, G. E.; Thomas, J. C.**
"Maximal aerobic power in women cadets at the U.S. Air Force Academy."
Aviation, Space and Environmental Medicine. 48(2): 154-155. 1977.

A sample of 17 women cadets of the U.S. Air Force Academy's Class of 1980 was assessed to determine their maximal oxygen consumption and percent body fat. The sample was selected using the ponderal index to insure a stratified sample of body types. The Short Balke protocol was used to determine VO2 max, and the Siri and the Keys and Brozek equations were used to find percent body fat. The Katch and McArdle equation was employed to determine body density. The average VO2 max for the women cadets was 46.1 ml/kg/min (SD = 4.0). Correcting for altitude, this value compares quite favorably with other reported values. The 24.8% mean body fat places these subjects well within the normal range for college age females. The female cadets of the Class of 1980 appear to be above their contemporaries in civilian life in circulo-respiratory fitness.

34. **Coyle, E. F.; Feiring, D. C.; Rotkis, T. C.; Cote, R. W. III; Roby, F. B.; Lee, W.; Wilmore, J. H.**
"Specificity of power improvements through slow and fast isokinetic training."
Journal of Applied Physiology. 51(6): 1437-1442. 1981.

College age males performed maximal two-legged isokinetic knee extensions three times per week for 6 wk at either 60 degrees/s (slow) or 300 degrees/s (fast) or both 60 and 300 degrees/s (mixed). The velocity specific and action specific (two-leg vs. one leg) improvements in peak torque (PT) were compared to a placebo group receiving low-level muscle stimulation. The slow group improved PT significantly ($P < 0.05$) more than the placebo group only at its training velocity (60 degrees/s) and more so when the specific two-legged training action was mimicked (+32% with two legs vs. +19% with one leg). The mixed group enhanced PT by 24 and 16% at their respective training velocities of 60 and 300 degrees/s. These improvements were significantly larger than placebo and also significantly larger than the 9% improvement observed at the mid velocity of 180 degrees/s. The training specificity demonstrated by the slow and mixed groups suggests that neural mechanisms contributed to their improvements in power. This is supported by their unchanging muscle morphology. Training solely at 300 degrees/s (fast) however improved PT significantly more than placebo not only at the training velocity (+18%), but also at a slower velocity of 180 degrees/s (+17%). The fast group demonstrated a significant enlargement (+11%) of type II muscle fibers. These data suggest type II fiber hypertrophy to be a plausible mechanism for the nonspecific improvement of the fast group; however, a neurological adaptation that enhances power at and below the training velocity cannot be excluded.

35. **Daniels, W. L.; Kowal, D. M.; Vogel, J. A.; Stauffer, R. M.**
"Physiological effects of a military training program on male and female cadets."
Aviation, Space and Environmental Medicine. 50(6): 562-566. 1979.

Tested at the beginning and the end of the 6-week training program which all incoming cadets (plebes) undergo upon entering the U.S. Military Academy were 29 males and 26 females (17-21 years old). The aerobic training consisted of running for 30 min 5-6 d/week at varied speeds depending upon performance in an initial 1.5-mile run test. Females responded to training with a significant increase ($p < 0.001$) in VO2 max from 46.0 $\pm$1.0 to 49.7 $\pm$0.8 ml/kg.min (7.9%). Males did not increase their initial VO2 max (59.4 $\pm$1.1 ml/kg.min) significantly. Both groups significantly reduced HRmax and percent body fat. Their initial VO2 max values and activity history accounted for the lack of a significant increase in this highly-fit population of males. Blood lactates were significantly decreased ($p < 0.05$) at the same two sub maximal workloads after training. The initial difference in aerobic power between males and females was reduced from 22% to 18%.

36. **Drinkwater, B. L.**
"Women and exercise: Physiological aspects."
Exercise, Sport and Science Review. 12: 21-51. 1984.

37. **Drinkwater, B. L.; Folinsbee, L. J.; Bedi, J. F.; Plowman, S. A.; Loucks, A. B.; Horvath, S. M.**
"Response of women mountaineers to maximal exercise during hypoxia."
Aviation, Space and Environmental Medicine. 50(7): 657-662. 1979.

Eight members of the American Women's Himalayan Expedition, ranging in age from 20-49, performed maximal exercise on a treadmill under normoxic and acute hypoxic (12.58% O2) conditions. Normoxic values for VO2 max were above average for all subjects and did not decline with age. The mean decrease in VO2 max (26.7%) during hypoxia was equivalent to that reported for younger males, which suggests that age was not a factor in response to hypoxia. Maximal heart rate, respiratory exchange ratio, oxygen pulse, and walk time were lower in hypoxia while ventilatory equivalent and blood lactate were higher. VEmax BTPS, was the same under both conditions. The combination of laboratory results and field observations by the Expedition physician suggest that women are capable of performing hard work at high altitude if they are in good condition and properly acclimatized.

38. **Drinkwater, B. L.; Kramar, P. O.; Bedi, J. F.; Folinsbee, L. J.**
"Women at altitude: Cardiovascular responses to hypoxia."
Aviation, Space and Environmental M edicine. 53(5): 472-477. 1982.

Six women mountaineers, 23-43 years of age, participated in a series of physiological tests prior to and during an expedition to Bhrigupanth (6798 m) in the Indian Himalayas. During a three-phase step test at sea level, carrying 0, 4.5, and 9.0 kg backpack weights, oxygen requirements represented 49.5-54.8% VO2 max. Recovery heart rates (HR) at 5-15 s were linearly related to exercise HR. At 4250 m, 5-15 s post exercise HR's were significantly higher than those at SL but returned to SL values after 3 min of rest. At 5000 m, HR's remained higher than those at SL throughout recovery. On returning to 4250 m after 3 weeks at higher altitudes, all post exercise HR's were back to SL levels. Supine HR's, higher at altitude than at SL during the ascent, returned to SL rates on return to 4250 m. Hemoglobin and hematocrit increased from 13.7 mg% and 42.4% at SL to 16.4 mg% and 52.6% after the climb. Resting blood pressure was significantly elevated at 4250 m during ascent but returned to SL values on the descent. During the cold pressure test, systolic pressure was unaffected by altitude; diastolic pressure increased less at altitude. While HR was unchanged at SL, a significant increase in HR was observed in post climb CPT tests, even though perceived discomfort decreased.

39. **Dusik, L. A.; Menard, M. R.; Cooke, C.; Fairburn, S. M.; Beach, G. N.**
"Concurrent validity of the ERGOS work simulator versus conventional functional capacity evaluation techniques in a workers' compensation population."
Journal of Occupational Medicine. 35(8): 759-767. 1993.

A prospective blinded cohort study was performed in an interdisciplinary vocational evaluation program to investigate the concurrent validity of the ERGOS work simulator in comparison to current methods of evaluation. Seventy men and eight women, aged 22 to 64 years, who attended for a 2-week physical capacity assessment participated in the study. Physical activity factors as defined by the Canadian Classification and Dictionary of Occupations and the American Dictionary of Occupational Titles were assessed for all subjects under three evaluation conditions: the ERGOS work simulator, an exercise-oriented physical evaluation by a rehabilitation therapist, and performance of project-format industrial tasks. In addition, 17 men and 7 women were assessed with VALPAR standardized work sample tests. The statistical significance of the relationships between results obtained by the various evaluation methods was examined. There was a strong correlation between the ERGOS dynamometry and the clinical assessment of strength for all standard movements tested ($P < 0.001$). The Methods Time Measurement rating by the ERGOS for dexterity variables, according to industrial engineering standards, tended to rate subjects as more restricted than did the clinical evaluators. There was a significant relationship ($P < 0.001$) between the "overall physical activity rating" from ERGOS dynamometry, clinical evaluation, and performance in an industrial workshop setting. There was also a significant relationship ($P < 0.001$) between the "overall physical activity rating" for endurance of a full workday produced by the 4-hour ERGOS evaluation and by the 2-week functional capacity evaluation. The results of this study indicate that a 4-hour ERGOS evaluation yields information on strength and endurance for industrial physical activity that is comparable with the information obtained from a comprehensive interdisciplinary 2-week functional capacity evaluation performed in multiple settings.

40. **Dyer, F. N.; Burke, W. P.**
Prediction of success in Airborne training.
Army Research Institute for the Behavioral and Social Sciences, Alexandria, VA, 1980, 37 pp., DTIC#AD-A136 340.

Physical fitness, Airborne training success and a number of other trainee variables were related for nearly 4,000 Airborne trainees. Success in training was found to be strongly associated with trainee physical fitness as measured by Army Physical Fitness Test events and performance on a modified Harvard Step Test. Large group differences found in Airborne training success between males and females and among officers, cadets and enlisted trainees were paralleled by large differences in physical fitness between and among these groups.

41. **Epperson, W. L.; Burton, R. R.; Bernauer, E. M.**
"The effectiveness of specific weight training regimens on simulated aerial combat maneuvering G tolerance."
Aviation, Space and Environmental Medicine. 56(6): 534-539. 1985.

To assess the effectiveness of muscle-strength (weight training) on simulated aerial combat maneuvering (SACM) G tolerance, seven young men were exposed to a 12-week program of whole-body weight training in which were measured, strengths of various muscle groups, body circumferences, body mass, and the percentage of body fat. The magnitudes of the weights used in training were used to measure muscle strength and were compared and correlated with each subject's SACM tolerance--defined as the total time that a subject could withstand continuous exposure to a 4.5 and 7.0 + Gz centrifuge profile using fatigue as his voluntary endpoint. Chest and biceps circumferences increased 4.2% and 3.1%, respectively; abdomen and thigh circumferences did not significantly change; body fat decreased 16.8%; and body mass increased 2.3%. Abdominal (sit ups) and biceps (arm curl) strengths increased 99% and 26.2%, respectively, and were highly correlated with SACM tolerance time ($p < 0.01$); leg (leg press) and chest strengths (bench press) made less significant contributions to the SACM tolerance time. A net increase in SACM tolerance times of 53% resulted from weight-training. Multiple regression analysis of all four muscle groups between weeks 1 and 12 with the SACM tolerance had a correlation of determination of 0.61.

42. **Epperson, W. L.; Burton, R. R.; Bernauer, E. M.**
"The influence of differential physical conditioning regimens on simulated aerial combat maneuvering tolerance."
Aviation, Space and Environmental Medicine. 53(11): 1091-1097. 1982.

The influence of physical conditioning on tolerance to a centrifugation profile called the Simulated Aerial Combat Maneuvering (SACM)--was determined using 24 young men as subjects. These subjects were assigned to groups as controls (no physical training, C), runners (R), and weight trainers (W). They followed a 12-week protocol of specified physical training. During this study, tolerance to the SACM, maximum oxygen consumption, muscle strength, and body composition were periodically determined. SACM tolerance was defined as the total time that a subject could withstand continuous exposure to a 4.5 and 7.0 +Gx centrifugation profile as determined by his voluntary endpoint of fatigue. The +Gx tolerance of the runners and controls increased at an average rate of 4 s/week during the course of the experiment. On the other hand, the weight trainers increased their G tolerance at an average rate of 15 s/week. The difference between group W compared with groups C and R was statistically significant at the 5% level. Fatigue scores indicate that group W subjects take longer to reach a given level of fatigue than did the subjects of the other groups. It appears therefore that a physical conditioning program of weight training will improve human tolerance to aerial combat maneuvers.

43. **Evans, W. J.; Winsmann, F. R.; Pandolf, K. B.; Goldman, R. F.**
"Self-paced hard work comparing men and women."
Ergonomics. 23(7): 613-621. 1980.

Six fit male subjects (23 years, 171 cm, 67 kg, maximal VO2=2.25 mmol/kg/min (50.3 ml/kg/min)) and 6 fit female subjects (22 years, 163 cm, 57 kg, maximal VO2=1.83 mmol/kg/min (41.1 ml/kg/min)) performed self-paced hard work while walking over four different terrains carrying no external load, 10 kg and 20 kg. Time on each course for individual subjects was used to determine speed and energy expenditure; heart rate was recorded as each subject completed each course. Walking speed and energy expenditure of the males were found to be significantly greater ($p < 0.05$) than those of the females over all terrains (blacktop road, 1.6 km; dirt road, 1.8 km; light brush, 1.4 km; heavy brush, 1.3 km) and for each load carriage condition. Relative energy expenditures of the males and females for all conditions were very similar ($p > 0.05$) and remarkably constant at a value close to 45% VO2 max. These data indicate that the voluntary hard work rate is dependent upon maximal aerobic power. The best predictor of speed for self-paced hard work of males and females for 1 to 2 hrs in duration appears to be based on 45% of maximal aerobic power.

44. **Falkel, J. E.; Sawka, M. N.; Levine, L.; Pandolf, K. B.**
"Upper to lower body muscular strength and endurance ratios for women and men."
Ergonomics. 28(12): 1661-1670. 1985.

This study examined possible gender differences for relative upper (elbow) to lower (knee) body strength and endurance, as well as relative flexion to extension strength and endurance. Seven women and nine men who were matched for both upper and lower body aerobic power were tested on an isokinetic strength instrument. Absolute isokinetic strength was lower ($P < 0.01$) for the women than the men for all measurements. When strength was expressed per lean body weight, the women were weaker ($P < 0.05$) only for elbow flexion strength. The women had a lower ($P < 0.05$) upper to lower body strength ratio for flexion, but not for extension. There were also no differences ($P > 0.05$) in isokinetic endurance fatigue decrements, or upper to lower body endurance ratios between genders. These data indicate that there were differences in absolute strength between the genders, but strength per lean body weight, as well as upper-to-lower body ratios for strength and endurance were similar for both genders. It was recommended that aerobic fitness and level of training be taken into account when strength and endurance were compared between the genders.

45. **Federal Bureau of Investigation Academy.**
Physical fitness testing in law enforcement.
Conference of the Major City Chief Association, National Executive Institute Associates and the Federal Bureau of Investigation, 1993.

46. **Fischer, M. D.; Wiegman, J. F.; Bauer, D. H.**
"Female tolerance to sustained acceleration - A retrospective study."
SAFE Journal. 22(2): 31-35. 1992.

In 1986, Gillingham et al. concluded that there were no differences in the relaxed or straining G-tolerance levels of men and women. He also reported no difference in their tolerance to +7 Gz sustained for 15 s. Since women may play an equal role in serving as aircrew on high-performance combat aircraft, their tolerance to high, sustained acceleration (>15 s and/or >+7 Gz) must be examined. The purpose of this study was to compare the +8 and +9 Gz tolerance of females and males. Data on 102 females and 200 males (flight surgeons, aerospace physiologists, and medical residents at Brooks AFB between the years 1986 and 1991) were obtained from the Armstrong Laboratory Centrifuge data repository. Results showed that a proportionate number of females and males attempted +8 Gz for 15 s (55.9% and 56.5%, respectively), but of those attempting the run, 63.2% of the females, compared to 80.9% of the males, completed the run. Fewer females and males attempted +9 Gz for 15 s (31.4% and 42.0%, respectively) with 59.4% of the females and 72.6% of the males completing the run. Chi Square analyses indicated a significant difference in the completion rates ($p < 0.05$) at the +8 Gz level, but no difference was detected at the +9 Gz level. We suggest that the differences found may be attributed to poor-fitting anti-G suits for the female subjects. Controlled centrifuge studies should be conducted to further investigate women's tolerance to high, sustained +Gz.

47. **Fleishman, E. A.; Gebhardt, D. L.; Hogan, J. C.**
"The measurement of effort."
Ergonomics. 27(9): 947-954. 1984.

A series of studies examined the reliability and validity of an index of perceived physical effort assessing the metabolic and ergonomic costs of task performance. In one set of studies, a wide variety of occupational and recreational tasks were rated on the physical effort required. Groups doing the rating included personnel specialists, non-specialists, males and females. Subjects had not necessarily performed the tasks previously, nor did they know the metabolic values of these tasks. In all groups, interrater agreement was high on the ratings of the effort required of these tasks. Also, predictions of various indices of actual metabolic costs from these ratings were high. In other studies, high correlations were obtained between ratings on the effort index and actual performance in manual materials-handling tasks. These studies also determined the particular physical ability requirements of tasks most related to perceived effort. The usefulness of the physical effort scale as a job-analysis method for physically demanding work is discussed.

48. **Frye, A. J.; Kamon, E.**
"Responses to dry heat of men and women with similar aerobic capacities."
Journal of Applied Physiology. 50(1): 65-70. 1981.

Four men and four women with similar VO2max (56.33 $\pm$ 4.05 and 54.08 $\pm$4.27 ml/kg/min, respectively) exercised up to 3 h at 30% VO2max during heat stress tests (HST) before and after acclimation to dry heat [dry-bulb temperature (Tdb)/wet-bulb temperature (Twb) = 48/25 degrees C]. Rectal (Tre), tympanic sweat on the chest (msw), and total sweat rate (Msw) were recorded. There were no differences in the responses of the women between phases of the menstrual cycle. Tre, Tty, Tsk, and Tdb at the onset of sweating were similar in both sexes before and after acclimation. The non acclimated men had significantly higher Msw and slower rise in Tre as compared to the non acclimated women. Following acclimation these differences were no longer evident. Acclimation produced an increase in Msw in both sexes that was characterized by an increase in sweating sensitivity (delta msw/delta Tre). It was concluded that sex alone does not determine responses to heat stress. Consideration should also be given to the relative cardiovascular strain, state of acclimation, and the ambient conditions.

49. **Gillingham, K. K.; Schade, C. M.; Jackson, W. G.; Gilstrap, L. C.**
Women's G tolerance.
School of Aerospace Medicine, Brooks AFB, TX, 1986, 11 pp., DTIC#AD-A177 986.

G tolerance of 102 women and 139 men subjected to Standard Medical Evaluation (Medeval) G Profiles were compared. Unpaired t-tests revealed no significant difference between the women and men in either relaxed or straining G tolerance. Covariance analysis controlling for differences in tolerance due to age, height, weight, and activity status revealed the women to have marginally lower tolerance; the analysis also identified height as a factor having a strong inverse relation to G tolerance, sex, and the height, weight, and activity status covariates were such that comparisons controlling for only one covariate made women appear more or less G tolerant than men, depending on which covariate was controlled. Thus, when the women were matched only by height to the men in the comparison group, the women's mean G tolerances were significantly lower than the men's. On standard Training G Profiles 88% of 24 women and 80% of 213 men completed the runs, but this difference was not significant. G tolerances of 47 women were measured on the Medeval Profiles both during and after menses, but no significant differences related to menstruation were found. No important differences between women and men in signs or symptoms of G stress were observed except for two instances of urinary stress incontinence in women during the Training Profiles. We conclude that women should not categorically be excluded from aircrew duties for reasons of G intolerance.

50. **Gordon, C. C.; Churchill, T.; Clauser, C. E.; Bradtmiller, B.; McConville, J. T.; Tebbetts, I.; Walker, R. A.**
1988 Anthropometric survey of U.S. Army personnel: Methods and summary statistics.
United States Army Research, Development and Engineering Center, Natick, MA, 1989, 652pp., TR-89/044.

Results of the 1987-1988 anthropometric survey of Army personnel are presented in this report in the form of summary statistics, percentile data and frequency distributions. These anthropometric data are presented for a subset of personnel (1774 men and 2208 women) sampled to match the proportions of age categories and racial/ethnic groups found in the active duty Army of June 1988. Dimensions given in this report include 132 standard measurements made in the course of the survey, 60 derived dimensions calculated largely by adding and subtracting standard measurement data, and 48 head and face dimensions reported in linear terms but collected by means of an automated headboard designed to obtain three-dimensional data. Measurement descriptions, visual indices, and a glossary of terms are included to help identify and locate dimensions. Also appearing in this report are descriptions of the procedures and techniques used in this survey. These include explanations of the complex sampling plan, computer editing procedures, and strategies for minimizing observer error. Tabular material in Appendices A and C are designed to help users understand various practical applications of the dimensional data, and to identify comparable data obtained in previous anthropometric surveys.

51. **Gragg, C. D.; Evans, C. E.; Gilliam, W. L.**
Ejection seat testing for females.
6585th Test Group (AFSC), Holloman AFB, NM, 1982, DTIC#AD-TR-82-68.

Anthropometric data from a recent survey of female pilots was analyzed and compared with available DoD anthropometric surveys. The comparison showed the two populations to be of different distributions, pointing out the deficiency in using the DoD survey in designing escape system tests covering female aviators. Further, analysis of two existing anthropometric surveys of male aviators taken in 1950 & 1967 found a considerable change in seventeen years, indicating a need for a new survey of the contemporary population. Recommendations were made to change Military Standards and Specifications on ejection system and ejection systems testing to reflect inclusion of female aviators.

52. **Griffin, J. W.; Tooms, R. E.; vander Zwaag, R.; Bertorini, T. E.; O'Toole, M. L.**
"Eccentric muscle performance of elbow and knee muscle groups in untrained men and women."
Medicine and Science in Sports and Exercise. 25(8): 936-944. 1993.

Maximal voluntary eccentric (ECC) and concentric (CON) capacity of knee and elbow muscle groups was investigated in healthy untrained men (N = 40) and women (N = 50), 21-67 yr of age. Purposes of the study were to describe torque-velocity and ECC-CON relationships, and to compare these relationships among muscle groups and between genders. Average torque was measured at angular velocities of 30 degrees and 120 degrees/s from knee flexor (KF), knee extensor (KE), and elbow flexor (EF) muscle groups unilaterally, using an isokinetic protocol including gravity compensation. Data were analyzed using ANOVA procedures, and a significance level of 0.01 was used for all hypothesis testing. Torque-velocity relationships were similar for each muscle group and gender; i.e., ECC average torque did not change as a function of velocity and CONC torque decreased as angular velocity increased. Women generated greater ECC relative to CONC torque than men in upper and lower extremity muscle groups. Muscle groups differed in ECC relative to CONC capacity in both men and women, with ECC/CONC ratios being greater for KE and EF than KF. In all muscle groups, the magnitude of ECC-CONC differences increased as angular velocity increased. Genders differed in relative strength balance between muscle groups, with men exhibiting greater KF/KE and EF/KF torque ratios than women for both ECC and CONC actions. Results of this study contribute to the body of knowledge concerning ECC muscle performance in untrained adult men and women. Findings concerning gender and muscle group differences in muscle performance should provide useful information for interpreting results of isokinetic testing of untrained adults, as well as for guiding training and rehabilitation programs.

53. **Hickson, R. C.; Hidaka, K.; Foster, C.**
"Skeletal muscle fiber type, resistance training, and strength-related performance."
Medicine and Science in Sports and Exercise. 26(5): 593-598. 1994.

The research goal was to attempt to clarify the consequences of increased strength on performance at sub maximal exercise intensities. Eight subjects (4 males, 4 females) completed a 3-day/wk, 16-wk resistance training regimen. After training, upper (bench press, BP) and lower (parallel squat, PS) extremity strength were increased by 23% and 37%, respectively. Performance at the same absolute work rates as before training was increased by 30-159% following training depending on intensity and type of exercise. Performance at the same relative work rates (80%, 60%, 40%) remained unchanged by the training for both exercises. Prior to training, PS repetitions at 40% were correlated ($r = 0.69$, $P < 0.05$) with the percentage of slow-twitch (ST) fibers in the vastus lateralis muscle. There were similar relationships at 40% ($r = 0.73$) and at 60% ($r = 0.83$) for the PS exercise after training. However, the resistance program did not result in greater relative sub maximal performance in individuals with a higher percentage of ST fibers. We conclude that strength improvement of up to 40% does not produce a strength-related performance deficit, when training and testing procedures are identical. Yet, these data do not rule out the potential of a strength-related repetition performance deficit. When subjects were equally divided by strength levels, those tested at the highest absolute resistance had significantly lower bench press repetition performance at 60% and 40% of the 1-RM than the subjects tested at the lowest absolute resistance.

54. **Hogan, J. C.; Bernacki, E. J.**
"Developing job-related preplacement medical examinations."
Journal of Occupational Medicine. 23(7): 469-476. 1981.

Federal regulations prohibiting discrimination in hiring require that employment selection procedures to evaluate applicants be based on job-related criteria. The preplacement physical examination used in employment, particularly in the placement of handicapped persons, must also be conducted in a job-related manner. This paper discusses the development and use of the physical examination in selecting and placing applicants for jobs in the workplace with special reference to handicapped persons and disabled veterans. It presents and justifies a method of performing these examinations in a manner consistent with humanistic and business goals as well as the goals of federal regulatory agencies prohibiting employment discrimination.

55. **Hogan, J. C.; Fleishman, E. A.**.
"An index of the physical effort reqired in human task performance."
Journal of Applied Psychology. 64(2): 197-204. 1979.

The relationship between ratings of perceived physical effort required in human task performance and associated metabolic expenditure was examined in two investigations. In each study, tasks, whose metabolic performance costs were known from the physical work assessment literature, were rated on the effort required to complete the task by subjects who did not know the metabolic information. Results of the first study revealed that personnel specialists (n=26) could discriminate among tasks of known metabolic differences and that their ratings of the effort required in task performance were highly correlated with actual metabolic costs. The second study replicated the procedures and results of the first study, using untrained male (n=26) and female (n=28) observers and examined sex differences in ratings of perceived effort. No rating sex differences were found beyond the level of chance. Implications of the results are discussed in terms of the development of an assessment index of the physical effort required in task performance.

56. **Hogan, J. C.; Ogden, G. D.; Gebhardt, D. L.; Fleishman, E. A.**
"Reliability and validity of methods for evaluating perceived physical effort."
Journal of Applied Psychology. 65(6): 672-679. 1980.

Two studies examined the reliability and validity of an index of perceived physical effort used to assess the metabolic and ergonomic costs of task performance. In the first study, tasks whose actual metabolic costs were available from the work physiology literature were rated by subjects (n=50) who had no knowledge of those costs. Rating scales included a perceived physical effort scale and nine physical ability requirement scales. Results indicated high correlations between two indices of metabolic costs and ratings of physical effort (r=0.75 and 0.72, respectively). High correlations were also obtained between metabolic costs and the ratings of various strength and stamina factors. In the second study, subjects (n=20) actually performed 24 separate manual materials-handling tasks whose ergonomic costs (work=force X distance) were calculated. Each completed task was rated on the index of perceived physical effort. Results indicate a substantial relationship (r=0.88) between actual foot-pounds of work and the obtained ratings of physical effort. Implications of the results are discussed in terms of the psychometric properties of the index and its usefulness as a job analysis method for physically demanding work.

57. **Hudgens, G. A.; Torsani-Fatkin, L. L.**
Human performance: Psychological and physiological sex differences (A selected bibliography).
Human Engineering Lab, Aberdeen Proving Ground, MD, 1980, 164 pp., DTIC#AD-A085 824.

The bibliography is a compilation of 1571 references dealing with, or related to, the effects of sex differences on human performance. The material is organized into four categories: An Overview of Sex Differences, Physiological

Sex Differences, Sex Differences in Cognitive and Motor Abilities, and Sex Differences in Personality. The time period covered is roughly from the 1930's into 1979. An index of first authors is included.

58. **Hudgens, G. A.; Torsani-Fatkin, L. L.**
Male and female performance on military related tasks.
Human Engineering Lab, Aberdeen Proving Ground, MD, 1983, 17 pp., DTIC#AD-P004 079.

A few years ago the Human Engineering Laboratory (HEL) began a serious consideration of the implications of greater utilization of female personnel in the Army. One program was initiated to provide answers to more immediate and applied problems such as those relating to anthropometric considerations in equipment and weapons design and to considerations of strength capabilities required in operating and repairing various types of equipment or weapons. Another program, which is the subject of this paper, was initiated to perform more basic investigations of performance variables which might have more subtle implications a little farther down the road. In this regard, we set forth to determine whether or not there exist sex differences in performance abilities in the more traditionally defined areas of behavior. Further, we sought to determine whether or not certain aspects of female soldier performance might be influenced by cyclical factors associated with the menstrual cycle.

59. **Jackson, A. S.; Osburn, H. G.; Laughery, K. R.**
"Validity of isometric strength tests for predicting performance in physically demanding tasks."
Proceedings of the Human Factors Society, 28th Annual Meeting. 452-454. 1984.

Job analysis has shown that many tasks in the energy industry are physically demanding. This study has examined the validity of an isometric strength test battery for predicting performance in work sample tests that simulated physically demanding tasks in coal mining and oil production. Since two of the work sample tests involved an endurance component, metabolically determined V02 (L/min) was used to measure arm endurance. All tests were administered to 25 male and 25 female physically fit subjects. Correlations between the isometric strength tests and the work sample tests ranged from 0.67 to 0.93. In addition, the isometric strength tests were more highly correlated with the endurance work sample tests than metabolically measured arm endurance. Slopes and intercepts of the male and female regression lines were homogenous. These results support the validity of isometric strength tests for predicting performance in physically demanding jobs.

60. **Johnson, D. M.**
Navy job-related male-female differences: Annotated bibliography.
Navy Personnel Research and Development Center, San Diego, CA, 1982, 144 pp., DTIC#AD-A114 388.

This bibliography presents the results of a literature review to identify areas in which research has shown males and females to differ significantly and reliably and that might account for male-female performance differences on Navy jobs traditionally held by men. The long-range objective of the project was to identify principles for job design for equal performability by men and women.

61. **Kannus, P.; Beynnon, B.**
"Peak torque occurrence in the range of motion during isokinetic extension and flexion of the knee."
International Journal of Sports Medicine. 14(8): 422-426. 1993.

The purpose of this study was to 1) assess the knee angles of hamstring and quadriceps peak torques at slow (60 degrees/sec) and moderate (180 degrees/sec) isokinetic velocities in healthy adult males (N = 143) and females (N = 106), 2) determine if velocity has an effect on these peak torque angles, and 3) determine if subject's age, sex, and muscle strength have an effect on the results. The Cybex II dynamometer was used to record the measurements. At 60 degrees/sec, the mean peak torque for the hamstrings occurred at 33 degrees for men and 37 degrees for women ($p < 0.001$) (0 degree = full extension). At 180 degrees/sec, the corresponding angles were 40 and 44 degrees ($p < 0.01$). In both groups the increase was 7 degrees ($p < 0.001$). At 60 degrees/sec, the peak torque angle of the quadriceps was 54 degrees in both groups. At 180 degrees/sec, the angle occurred significantly later in men (11 degrees later) and in women (10 degrees later) ($p < 0.001$ for both). Subject's age (18 to 40 years) did not affect the results. In female hamstrings, the knee angle of peak torque had a highly significant ($p < 0.001$) negative correlation to muscle strength; that is, in female hamstrings, the peak torque angles occurred later in the range of motion when muscle strength decreased. This possibly explained the difference observed between men and women in the peak torque angles of hamstrings. In conclusion, people involved in isokinetic testing of muscular performance should be aware that the peak torque occurs later in the range of motion with increasing angular velocity, especially when testing weak muscle groups. In high angular velocities this may become a problem since the limb may pass the optimal joint position for muscular performance, and the recorded peak torque may not represent the subject's maximal torque capacity.

62. **Karim, B.; Bergey, K. H.; Chandler, R. F.; Hasbrook, A. H.; Pursell, J. L.; Snow, C. C.**
A preliminary study of maximal control force capability of female pilots.
FAA Civil Aeromedical Institute, Oklahoma City, OK, 1972, 17 pp., DTIC#AD-753 987.

The growing number of female pilots entering the field of civil aviation has suggested the need for a study of the maximum allowable forces which should be specified for operating aircraft controls. Therefore, a study was made of the maximal voluntary forces which a sample of 25 female pilots could exert on each flight control. Further, the percent of maximal strength versus endurance relationship reported by other investigators was studied for this population in operating each control. The percent of maximal strength versus endurance relationship was established and compared with the results of other investigators. The results obtained indicate a need for further study of the subject in simulated and actual flight.

63. **Keyserling, W. M.; Herrin, G. D.; Chaffin, D. B.**
"Isometric strength testing as a means of controlling medical incidents on strenuous jobs."
Journal of Occupational Medicine. 22(5): 332-336. 1980.

This investigation was performed to determine if isometric strength tests can be used to select workers for strenuous jobs and to reduce occupational injuries which are caused by a mismatch between worker strength and job strength requirements. Twenty jobs in a tire and rubber plant were studied biomechanically to identify critical strength-demanding tasks. Four strength tests were designed to simulate these tasks, and performance criteria were established for passing the tests. New applicants were administered the tests during their preplacement examinations to determine if they possessed sufficient strength to qualify for the jobs. The medical incidence rate of employees who were selected using the strength tests was approximately one-third that of employees selected using traditional medical criteria. It was concluded that isometric strength tests can be used to reduce occupational injuries and should be considered for implementation in industries with strenuous jobs.

64. **Keyserling, W. M.; Herrin, G. D.; Chaffin, D. B.; Armstrong, T. J.; Foss, M. L.**
"Establishing an industrial strength testing program."
American Industrial Hygiene Association Journal. 41(10): 730-736. 1980.

This study was performed to develop and evaluate a scheme for matching the strength of workers to the strength demands of their jobs. Biomechanical analyses were performed on production jobs in an aluminum reduction plant to identify and quantify strength demands. These data were used to design a set of nine strength tests which simulated job activities with the greatest strength requirements. A cross section of plant employees assigned to these jobs was strength tested and monitored for medical incidents for a period of over two years. Significant relationships were found among job strength requirements, worker strengths, and medical incidents. Workers with strength abilities (as determined by the tests) less than job strength requirements suffered a higher rate of medical incidents than workers whose strength abilities matched or exceeded job demands. It was concluded that strength testing can be used to identify workers who would be at increased risk of suffering medical incidents if placed on jobs which exceeded their strength abilities.

65. **Krock, L. P.**
"Russian Air Force: Pilot selection and retention procedures."
Presidential Commission on the Assignment of Women in the Armed Forces. 1992.

Increasing demands placed upon pilots of modern tactical aircraft have produced a situation wherein protection from high-G forces can no longer be accomplished by technical means alone. Responding to this concern the Russian Air Force has established medical and performance criteria for their high-performance jet pilots. Furthermore, the "elite" high-performance pilot is frequently evaluated for medical or physical (strength) changes that could affect flight performance. Methods employed during these selection and evaluation examinations include a multitude of clinical and functional tests. Careful screening has been successful in detecting unfavorable physiologic responses in pilot candidates. In addition, continued surveillance of the flying personnel has the advantage of identifying problems in psychophysiologic health before performance decrements are produced. The purpose of this paper is to share the nature of the Russian pilot selection and surveillance procedures, so we may benefit from Russian experience.

66. **Kroemer, K. H. E.**
Human force capabilities for operating aircraft controls at 1, 3, and 5 Gz.
Air Force Aerospace Medical Research Lab, Wright-Patterson AFB, OH, 1975, DTIC#AD-A011 545.

The maximum isometric forces adult male subjects could exert at eight locations of hand-operated aircraft controls were measured at +1, +3, and +5 Gz. Forces were measured in two vertical and four to eight horizontal directions. Selected anthropometric dimensions were obtained on the subjects and compared with those from the 1967 USAF anthropometric survey of flying personnel. Summary statistics including the mean, standard deviation, coefficient of variation, symmetry kurtosis, and selected percentiles are presented for each of the 60 force exertion measures.

67. **Kroll, W.; Kilmer, W. L.**
Coordination mechanism in fast human movements--Experimental and modeling studies. Volume 2.
Massachusetts University, Amherst, MA, 1982, 383 pp., DTIC#AD-A168 165.

Results of Year 2 are presented and include: (a) the theoretical rationale and strategy for analysis of neuromotor coordination mechanisms in fast limb movements; (b) a progress report of experimental and modelling studies conducted during Year 2; (c) an article describing an EMG-level mathematical model of fast-arm movement; (d) an article describing the stability of delay actions for simple human stretch reflexes; (e) an article describing theoretical bases for the sensory imparted learning model; (f) an article describing the prediction of male and female isometric arm strength through anthropometric measures; (g) experimental results of gender differences and muscle fatigue effects upon speed of neuromotor coordination mechanisms; and (h) experimental results of muscle fatigue upon speed of movement and the effects of tonic vibratory response upon neuromotor coordination mechanisms.

68. **Kues, J. M.; Rothstein, J. M.; Lamb, R. L.**
"The relationships among knee extensor torques produced during maximal voluntary contractions under various test conditions."
Physical Therapy. 74(7): 674-683. 1994.

BACKGROUND AND PURPOSE. The purpose of this study was to describe the relationships among measurements of torque produced during selected maximal voluntary contractions of the quadriceps femoris muscles. SUBJECTS. Twenty non-disabled women, ranging in age from 21 to 33 years (X=25, SD=3.5), volunteered to participate in the study. METHODS. The subjects were tested on a dynamometer. Subjects performed isometric contractions at velocities of 30 deg, 90 deg, 120 deg, and 180 deg/s. Isometric knee extensor torques, concentric knee extensor peak torques, and eccentric knee extensor peak torques were determined for each subject. Coefficients of determination (r^2) and linear regression equations were calculated to determine the strength and nature of the relationships among the measurements. RESULTS. The coefficients of determination ranged from 0.60 to 0.94. CONCLUSION AND DISCUSSION. The torque measurements were moderately to highly correlated, suggesting that the measurements obtained during different maximal voluntary contractions may be assessing similar components of performance.

69. **Laubach, L. L.**
"Comparative muscular strength of men and women: A review of the literature."
Aviation, Space and Environmental Medicine. 47(5): 534-542. 1976.

The results from nine separate studies reporting comparable static and dynamic muscle strength measurements between men and women have been reviewed. The statistical data from these studies are presented in graphical and tabular form illustrating, when appropriate, the mean $\pm$ 1 SD, and the mean percentage difference between men and women for the given measurement. The following differences in strength measurements were observed: (a) upper extremity strength measurements in women were found to range from 35 to 79% of men's, averaging 55.8%; (b) lower extremity strength measurements in women ranged from 57 to 86% of men's, averaging 71.9%; (c) trunk strength for women ranged from 37 to 70% of men's, averaging 63.8%; (d) dynamic strength indicators revealed that women were from 59 to 84% as strong as men, with an average of 68.6%. In view of the wide range of mean percentage differences in muscle strength measurements between men and women, the author stresses the importance of exercising extreme care in making extrapolations from such data and recommends a method for making such extrapolations when the absence of direct measurements makes this necessary.

70. **Leeper, R. C.; Hasbrook, A. H.; Purswell, J. L.**
Study of control force limits for female pilots.
FAA Civil Aeromedical Institute, Oklahoma City, OK, 1973, 33 pp., DTIC#AD-777 839.

The study described in this paper was the second phase in a ground-based control force testing program conducted by the University of Oklahoma and the Civil Aeromedical Institute of the Federal Aviation Administration located in Oklahoma City, Oklahoma. A Convair-340 simulator, modified to conform to a typical civil aviation aircraft, was used for the study. Female pilots were used as subjects. The data show that the current FAR 23.143 control force limits for general aviation aircraft are too high for a majority of U.S. female pilots. Data on strength capabilities of women for operating aircraft controls are presented in the form of prediction equations for level of control force versus time.

71. **Lillegard, W. A.; Terrio, J. D.**
"Appropriate strength training."
Medical Clinics of North America. 78(2): 457-477. 1994.

Strength training stimulates predictable cardiovascular and neuromuscular responses. The cardiovascular responses result in nonpathologic concentric left ventricular hypertrophy with preservation of ejection fraction and no diastolic dysfunction. Resting heart rates and blood pressures in strength-trained individuals remain unchanged or decrease slightly. Strength gains occur from enhanced neuromuscular activation over the initial 8 weeks and from increased muscle fiber density and hypertrophy during subsequent weeks. Significant strength gains are possible in all populations, including children, women, and the elderly, when exposed to an adequate strength-training program. Strength training can also be a valuable adjunct in cardiac rehabilitation with the possible exception of patients with baseline abnormal left ventricular function.

72. **Lyons, T. J.**
"Women in the fast jet cockpit--Aeromedical considerations."
Aviation, Space and Environmental Medicine. 63(9): 809-818. 1992.

Historically women have demonstrated the capacity to be successful aviators. A review of the scientific literature between 1966 and 1991 pertinent to the role of women in military aviation revealed only minor differences of questionable operational significance between men and women. Women may be more susceptible to motion sickness, radiation, and decompression sickness than men, but may be more resistant to cold immersion and altitude sickness. Although men are on the average, larger, stronger, and more aerobically fit than women, there are large variations within each sex and a large overlap between the sexes. Gender differences in work performance, G tolerance, heat stress, and injury rate disappear when allowance is made for size, strength, and fitness. Aeromedical selection criteria can, thus, address individual characteristics without reference to gender. The possibility of fetal damage in the early stages of pregnancy (before diagnosis) appears to be perhaps the biggest single medical concern in allowing women access to all aviation and space careers.

73. **Lyons, T. J.**

Women in the military cockpit.
Armstrong Lab, Brooks AFB, TX, 1991, 47 pp., DTIC#AD-A238 808.

Historically women have demonstrated the capacity to be successful aviators. Recent participation of women in combat roles and in military aviation has, however, aroused controversy. The scientific literature pertinent to the role of women in military aviation was reviewed. Cognitive differences between men and women account for less than 5% of the population variance and their implication for aviation is unknown. The effect of cyclic hormone fluctuations on performance is poorly understood. Men are, on the average, larger, stronger, and more fit than women, although there are large variations within each sex and a large overlap between the sexes. Difference in work performance, injury rate, etc., disappear when size, strength, and fitness are controlled for. Selection criteria can thus address size, strength, and fitness requirements without reference to sex. Several minor differences of questionable operational significance may exist. Women may be more susceptible to motion sickness, heat stress, radiation (cancer and endometriosis), and decompression sickness than men, but may be more resistant to cold stress and altitude sickness. The possibility of fetal damage in the early stages of pregnancy (before diagnosis of pregnancy) appears to perhaps the biggest single medical concern in allowing women access to all aviation/space careers.

74. **Marriott, B. M.; Grumstrup-Scott, J.**
Body composition and physical performance.
Committee on Military Nutrition Research, National Academy of Sciences, Washington, DC., 1992, 372pp., DTIC#AD-A255 627.

The relationship of body composition to performance of physical tasks is of major interest to the military. Not only is it important in the decisions of acceptance or rejection of recruits for military service, but it also has significant implications for the individual relating to retention and advancement while in the services. There are financial implications as well for the military services, due to the high cost of training replacements, when individuals are discharged for failure to meet the established standards. The discharge of highly trained and experienced specialists has significant additional implications concerning unit readiness and performance. The application of body composition standards in the military on a rational and equitable basis based on ethnicity, gender, and age is therefore an important issue.

75. **Mayer, F.; Horstmann, T.; Rocker, K.; Heitkamp, H. C.; Dickhuth, H. H.**
"Normal values of isokinetic maximum strength, the strength/velocity curve, and the angle at peak torque of all degrees of freedom in the shoulder."
International Journal of Sports Medicine. 15 Suppl 1: 19-25. 1994.

Many acute and chronic complaints in the shoulder joint are due to a reduced active stabilization capacity. Procedures to measure isokinetic strength are used to objectify the muscle deficits and imbalances of various muscle groups. In this study, standard values and reference ranges were determined for peak torque (PT), strength/velocity curve, and range of motion (ROM) at peak torque in the shoulder in 19 untrained women and 32 men. Differentiation was made by the individual degrees of freedom of the shoulder joint and the various types of work (concentric, isometric, eccentric). Moreover, the influence of height, body weight, and body mass index on isokinetic maximum strength development was investigated. It was found that it is necessary to distinguish between the various movements and types of work in development of peak torque. A decrease in maximum strength is observed in the sequence extension, adduction/flexion, abduction/internal rotation, external rotation. The maximum strength of men was determined to be higher than that in women. ROM shows a wide fluctuation and does not possess high validity. Height, as well as body weight and body mass index have only slight influence on the isokinetic maximum strength in the shoulder of untrained men and women.

76. **McDaniel, J. W.**
Male and female capabilities for operating aircraft controls.
Air Force Aerospace Medical Research Lab, Wright-Patterson AFB, OH, 1981, 4 pp., DTIC#AD-A098 256.

There has long been concern that the resistance of some aircraft controls is too large. Now that the Air Force has both male and female pilots, that concern is greater. The Workload and Ergonomics Branch of AFAMRL has just completed a study of the physical strength and endurance capabilities of 61 male and 61 female subjects in a stick-controlled aircraft simulator. Additionally, 110 of these subjects completed a nine-week exercise training program to strengthen muscles used on aircraft controls. Results show weak males and weak females have similar leg strength. The arm strength of strong females was similar to that of weak males, however. Physical training improved leg strength more than arm strength. Males and female had similar increases in strength due to physical training. Most of the females and some males fell below the resistance specification for current aircraft.

77. **McDaniel, J. W.**
"Strength capability for operating aircraft controls."
Advances in Industrial Ergonomics and Safety VI. 705-712. 1994.

Maximum isometric strength for operating aircraft controls was measured on 451 men and 252 women from two populations: the U.S. Air Force Academy (AFA) and Officer Training School (OTS). Subjects performed maximum isometric exertions on stick, wheel, and pedal aircraft-type flight controls. Of these 703 subjects, 630 (199 AFA men, 249 OTS men, 115 AFA women, and 67 OTS women) met the body size requirements for Air Force pilots. Most of the 630 had been selected for pilot training. Results showed men were stronger than women, AFA men and women were stronger than OTS men and women, and available strength differed with the direction of force. Strength screening had great influence on population strength, but for well-conditioned subjects, additional physical conditioning showed no improvement.

78. **McDaniel, J. W.; Robbins, G.**
"The strength of women for activation of ejection seat controls."
Proceedings of the Annual International Industrial Ergonomics and Safety Conference. 1992.

One hundred and four female volunteers performed static strength tests on side and center mount ejection seat controls with left, right, and both hands. Results indicated that all subjects were able to operate the side handles with one hand, with strength to spare. The minimum left hand torque was 25.3 N-m (224 in-lb), with 19.8 N-m (175 in-lb) being the current requirement. When using the center handle, the minimum two-hand force was 274 N (61.5 lb), with 218 N (49 lb) being the requirement. Strength was not found to be meaningfully related to body size or mass.

79. **McDonald, D. G.; Beckett, M. B.; Hodgdon, J. A.**
"Psychological predictors of physical performance and fitness in U.S. Navy personnel."
Military Psychology. 3(2): 73-87. 1991.

The primary purpose of this study was to assess the role of selected psychological variables (mood scales, physical estimation and attraction, self-concept, and personality scales) in predicting physical performance and fitness measures in a sample of military volunteers. Subjects were 102 (64 men, 38 women) active-duty U.S. Navy personnel. Subjects performed a number of physical performance and fitness tasks (including a 1.5-mile run, a carrying task, and an incremental treadmill test) and completed a battery of standardized questionnaires. Results were analyzed by canonical correlation and multiple regression techniques. Although the men and women differed significantly on measures of size, body fat, and physical capacity, there were no significant gender differences in scores on questionnaire measures. The primary findings of this study are as follows: (a) Questionnaire measures, most notably Attraction, Estimation, and Physical Self-Concept scores, can be used to predict both performance and fitness measures in a group of U.S. Navy active-duty personnel; (b) there are no differences between men and women in significance of primary questionnaire measures to predict performance or fitness measures, with Attraction, Estimation, and Physical Self-Concept scores being the best predictors among all questionnaire measures in both gender groups. Other significant predictors were Ambition and Prudence for men and Vigor, Anger, and Confusion for women. Theoretical implications are discussed.

80. **Miller, A. E.; MacDougall, J. D.; Tarnopolsky, M. A.; Sale, D. G.**
"Gender differences in strength and muscle fiber characteristics."
European Journal of Applied Physiology. 66(3): 254-262. 1993.

Strength and muscle characteristics were examined in biceps brachii and vastus lateralis of eight men and eight women. Measurements included motor unit number, size and activation and voluntary strength of the elbow flexors and knee extensors. Fiber areas and type were determined from needle biopsies and muscle areas by computerized tomographical scanning. The women were approximately 52% and 66% as strong as the men in the upper and lower body respectively. The men were also stronger relative to lean body mass. A significant correlation was found between strength and muscle cross-sectional area (CSA; $P \leq 0.05$). The women had 45, 41, 30 and 25% smaller muscle CSAs for the biceps brachii, total elbow flexors, vastus lateralis and total knee extensors respectively. The men had significantly larger type I fiber areas (4597 vs 3483 microns^2) and mean fiber areas (6632 vs 3963 microns^2) than the women in biceps brachii and significantly larger type II fiber areas (7700 vs 4040 microns^2) and mean fiber areas (7070 vs 4290 microns^2) in vastus lateralis. No significant gender difference was found in the strength to CSA ratio for elbow flexion or knee extension, in biceps fiber number (180,620 in men vs 156,872 in women), muscle area to fiber area ratio in the vastus lateralis 451,468 vs 465,007) or any motor unit characteristics. Data suggest that the greater strength of the men was due primarily to larger fibers. The greater gender difference in upper body strength can probably be attributed to the fact that women tend to have a lower proportion of their lean tissue distributed in the upper body. It is difficult to determine the extent to which the larger fibers in men represent a true biological difference rather than a difference in physical activity, but these data suggest that it is largely an innate gender difference.

81. **Mital, A.; Ayoub, M. M.**
"Modeling of isometric strength and lifting capacity."
Human Factors. 22(3): 285-290. 1980.

Two categories of prediction models have been developed. Category one models predict isometric shoulder strength, leg strength, arm strength, back strength, and composite strength of male and female industrial workers based upon operator characteristics (age, sex, and anthropometric variables). Category two models predict lifting capacity of male and female industrial workers by utilizing their individual and anthropometric characteristics. The lifting capacity models can be used to predict the amount of weight an individual can lift for different height ranges at various frequencies of lift. A high multiple partial correlation coefficient ($r \geq 0.95$) was obtained when lifting capacity models were used to predict the amount of weight an individual can handle by using his predicted isometric strengths (from category one models) and personal characteristics (age, sex, and anthropometric variables).

82. **Mogenson, F. E.; Stobbe, T. J.**
"Investigation of the effect of exertion length on measured isometric strength."
Proceedings of the Human Factors Society, 29th Annual Meeting. 504-507. 1985.

Isometric strength testing has been shown to be an effective method of matching employee strength capability to job strength requirements. Increased blood pressure and other cardiovascular effects produce undesirable stress in test subjects and could be reduced by using a shorter test if no additional information is gained by using a longer test. If several muscle groups are involved in an isometric strength test the "Ergonomics Guide for Assessment of Human Static Strength" suggests that pilot studies be performed to assure adequate time for a subject to seek and maintain a maximum voluntary effort for a period of at least three seconds. This study was designed to quantitatively investigate the effect of exertion length on measured strength for three strength tests simulating industrial activities. Twenty student volunteers (10 males, 10 females) performed each test for both a five second and three second duration. The force measured during selected one to four second intervals or both the five second and three second tests were compared. This study indicates that it may be possible to decrease the length of isometric tests without reducing the validity of resulting strength measurements, thus reducing the stress on the subjects.

83. **Mullins, W. R.**
Female combat helicopter pilot selection criteria.
Army Command and General Staff College, Fort Leavenworth, KS, 1993, DTIC#AD-A273 935.

This study investigates selection criteria for selecting female aviators for training in combat helicopters (AH-64, AH-1, OH-58D, and RAH-66). Selection for such training would occur as either part of the multi-track program of instruction used in the current Initial Entry Rotary Wing flight training course, or as transition training for already qualified aviators. Analysis included a review of: current Army Regulations governing prerequisites for combat helicopter maintenance test pilot training; Initial Rotary Wing selection criteria for combat helicopter tracks (AH-1 and OH-58); Aviation Branch Personnel Manager interviews; Combat Helicopter Manprint/Anthropometric restrictions; Standards of medical fitness; Anthropometric standards; and previous reports on female performance in Initial Entry Rotary Wing training. Conclusion supports selecting females for combat helicopter training using the same selection criteria currently used for choosing males for such training. Study recommends additional research in aircraft accommodation requirements; social-psychological aspects; and physical body strength requirements.

84. **Murphy, M. M.; Patton, J. F.; Frederick, F. A.**
Comparative anaerobic power of males and females.
Army Research Institute of Environmental Medicine, Natick, MA, 1985, 19 pp., DTIC#AD-A151 960.

The purpose of this study was to determine the differences in anaerobic power between males and females and the contribution of anthropometric variables in accounting for these differences. Eighteen female and nineteen male subjects performed the Wingate test as a measure of anaerobic power (AnP). Each subject pedaled maximally for 30 seconds against a resistance of 4.41 joules/pedal revolution/kg body weight on a modified Monark ergometer which allowed instantaneous application of resistance. Revolutions were determined by a computer interfaced frequency counter. Thigh volume (TV) by water displacement, lean body mass (LBM) from skinfolds and body weight (BW) were used as anthropometric variables. Absolute AnP of males was significantly higher than females, as were pedal revolutions. The differences between genders decreased when power was expressed in terms of TV, BW, and LBM, in that order. The data revealed that a larger portion of the between-gender variation in AnP can be accounted for by the anthropometric variables. However, a significant portion remains that must be explained by the individual muscle's potential for glycolytic energy production.

85. **Myrsten, A. L.; Lundberg, U.; Frankenhaeuser, M.; Ryan, G.; Dolphin, C.; Cullen, J.**
Sex-role orientation as related to psychological and physiological responses during achievement and orthostatic stress.
Stockholm University, Department of Psychology, Sweden, 1984, 19 pp., DTIC#AD-B080 430.

The Bem Sex-Role Inventory was used to select, from an Irish student population, females and males, who differed with regard to feminine and masculine personality characteristics. Four groups were established for each sex: 1. subjects with low scores in both femininity and masculinity, i.e., "undifferentiated" subjects; 2. subjects with high scores in both femininity and masculinity, i.e., "androgynous" subjects; 3. subjects with high scores in femininity and low scores in masculinity; 4. subjects with high scores in masculinity and low scores in femininity. The Cattell 16PF scale showed that the undifferentiated groups were more reserved and detached and more cautious and taciturn than the androgynous groups. Each subject was exposed to mental stress in one session and orthostatic stress in another session. Mental stress was induced by five different intellectual performance tests. Males and females differed significantly only on a test of perceptual speed, females performing better than males, as expected. The group of androgynous females was superior to all other groups on four of the five performance tasks. The group of androgynous males was not superior in terms of objective performance but reported feeling more confident and satisfied with their performance than most other groups, particularly the undifferentiated males. Blood pressure and heart rate were significantly elevated in all groups during both stress conditions. Heart rate was significantly higher in the high-femininity and androgynous females than in the other female groups.

86. **Newsom, B. D.; Goldenrath, W. L.; Winter, W. R.; Sandler, H.**
"Tolerance of females to +GZ centrifugation before and after bedrest."
Aviation, Space and Environmental Medicine. 48(4): 327-331. 1977.

Because women may be included as passengers in the proposed Space Shuttle System, this study was designed to investigate the +GZ tolerance of women and the possible degradation of this tolerance after a period of weightlessness as simulated by bedrest. Twelve healthy Air Force Flight Nurses served as test subjects. Over a 1-week period, each subject was exposed to +GZ levels starting at +2 GZ and increasing by 0.5 GZ increments to a gray-out point. This point was determined by peripheral vision loss with a standard lightbar and by reverse blood flow in the temporal artery. Ultimately, each woman was subjected to three runs at the +3 GZ level; each run was approximately 55 min long, separated by 5-min rest periods. Eight subjects with the best tolerance times were selected for 14 d of bedrest in a horizontal position; the other four were ambulatory controls. Tests before bedrest, immediately following, and 5 d later showed that average +GZ tolerance decreased by 67% after bedrest.

87. **Pandolf, K. B.; Cain, W. S.**
"Constant effort during static and dynamic muscular exercise."
Journal of Motor Behavior. 6(2): 101-110. 1974.

Ss maintained sense of effort constant over time for two tasks: static handgrip contractions held for 3 min., and dynamic exercise performed on a bicycle ergometer for 12 min. Initial force of handgrip ranged from 18-85% of maximum voluntary contraction, and initial power output for cycling ranged from a level that elicited 30% to a level that elicited 85% of maximum oxygen uptake. Except at the lowest levels of effort, constant-effort functions (force vs time and power output vs time) declined sharply at first, and more slowly thereafter. Handgrip declined toward a steady state (asymptote) force near 15% of maximum voluntary contraction and functions for cycling toward a steady state power output that elicited oxygen uptakes equal to or less than approximately 50% of maximum. The two types of constant-effort functions reflect basic differences between static and dynamic tasks.

88. **Pandolf, K. B.; Sawka, M. N.; Shapiro, Y.**
Factors which alter human physiological responses during exercise-heat acclimation.
Army Research Institute of Environmental Medicine, Natick, MA, 1985, 22 pp., DTIC#AD-A160 580.

Researchers generally agree that high aerobic fitness achieved through physical training will reduce the physiological strain to exercise in the heat, but does not replace the benefits of an exercise-heat acclimation program. In addition, high aerobic fitness is hypothesized as a major factor in the small decay and rapid re-acclimation of individuals after they ceased exercising in hot environments. However, recent work from our laboratory suggests that improved aerobic fitness by physical training must be associated with significant elevations in core temperature during the training process in order to improve exercise heat tolerance. Two recent studies comparing men and women with similar aerobic fitness indicate no major physiological differences between genders in both humid and dry heat for cardiovascular and thermoregulatory responses to these environments either before or after acclimation. Our laboratory has reported that after exercise-heat acclimation under wet conditions (mild or hot), females tolerate the heat in a more efficient fashion than males, while under hot-dry conditions males seem to be at some physiological advantage. Even fewer studies are reported which evaluate physiological differences in heat tolerance to exercise in relation to age. In general, exercise-heat tolerance is reduced in pre-pubertal children (boys and girls) and older adults (men and women) compared to young men and women. However, aerobically fit older adults seem to have far fewer decrements in the performance of exercise in the heat than less fit older adults.

89. **Pandolf, K. B.; Sawka, M. N.; Shapiro, Y.**
Physiological differences between men and women in exercise-heat tolerance and heat acclimation.
Army Research Institute of Environmental Medicine, 1985, 28 pp., DTIC#AD-A152 048.

The responses of men to changes in environmental temperature have provided a basis for the understanding of human heat tolerance and thermoregulation. There appears to be less certainty about the thermoregulatory patterns of women. Physiological responses to heat stress may differ between genders due to several factors which include the lower cardiorespiratory fitness, higher body fat content, lower body weight, and lower skin surface area and higher surface area-to-mass ratio of women compared to men. In addition, fluctuating hormonal levels of estrogen and progesterone accompanying the menstrual cycle may influence women's tolerance to heat stress. Since the U.S. Army is currently composed of greater than 10% females, it has become necessary to examine heat responses of females to exercise-heat stress and heat acclimation. Our Institute has conducted experiments comparing men and women for exercise-heat tolerance and acclimation over a wide range of environmental conditions. Both genders have been exposed to a comfortable climate (20 degrees C, 40% rh), several hot-wet (37 degrees C, 80% rh; 35 degrees C, 90% rh; 35 degrees C, 79% rh; 32 degrees C, 80% rh), and hot-dry (54 degrees C, 10% rh; 49 degrees C, 20% rh) environments while performing various exercise-rest cycles ranging from two to four hours in duration. Genders were matched for aerobic fitness, surface area-to-mass ratio and/or percent body fat. During the two-hour hot-dry exposures, heart rate and core temperature were generally lower for males than females, while no differences in sweat loss were observed. During hot-wet exposures, core temperature and sweat loss were generally lower in females than males. These data indicate that females and males react in a physiologically similar manner under comfortable environmental conditions, while females seem to tolerate hot-wet climates slightly better than males, and males slightly better tolerate hot-dry conditions. In subsequent experimentation, significant differences were not generally found between the genders for heart rate, core temperature and sweat loss during additional hot-wet and hot-dry exposures. Further, males and females acclimated to a representative hot-dry environment (49 degrees C, 20 % rh) at the same rate. In spite of similar rates of achieving heat acclimation, final core and mean skin temperatures remained higher for the females after acclimation as well as before acclimation. These same heat-acclimated men and women were exposed to these same hot-dry conditions (49 degrees C, 20% rh) for four rather than two hours to determine the effect of prolonged exercise in the heat on physiological differences between the genders. It was concluded that prolonged exposure to exercise-heat stress did not enhance physiological differences in responses to dry-heat exposure. Also, when hypohydrated (5% of base line body weight), during exercise in either a comfortable (20 degrees C, 40% rh), hot-wet (35 degrees C, 79% rh), or hot-dry (49 degrees C, 20% rh) environment, men and women respond in a physiologically similar manner. In conclusion, when genders are similar with regard to aerobic fitness level, surface area-to-mass ratio and percent body fat, they do not differ dramatically in exercise-heat tolerance and rate of heat acclimation; these reactions are not altered between the genders when hypohydrated.

90. **Petrofsky, J. S.; Burse, R. L.; Lind, A. R.**
"Comparison of physiological responses of women and men to isometric exercise."
Journal of Applied Physiology. 38(5): 863-868. 1975.

The volunteers for this study were 83 women, aged 19-65 yr, drawn from several different occupations. Three minutes after exerting maximal handgrip strength (MVC) each subject held a tension of 40 percent MVC to fatigue. Blood pressures and heart rates were measured before, during, and after the endurance of contraction. Age was associated with a reduction of strength of the women, whereas their endurance at 40 per cent MVC increased. There was evidence that menopause enhanced those age effects for strength and endurance. At rest, age was associated with a decreased heart rate. As expected, the heart rates of all the women increased during the endurance contraction. But that increase was greater for the younger than for the older women, thereby exaggerating the difference due to age already seen at rest. Systolic blood pressure at rest was higher with age and, in a similar manner, that relationship was also exaggerated throughout the isometric contraction. Diastolic blood pressure, however, was not changed with age at rest, and although the diastolic pressure increased during the isometric exercise, the rate of increase was unaffected by age. The results obtained are compared with those from a similarly large number of men examined in identical circumstances.

91. **Petrofsky, J. S.; LeDonne, D. M.; Rinehart, J. S.; Lind, A. R.**
"Isometric strength and endurance during the menstrual cycle."
European Journal of Applied Physiology. 35(1): 1-10. 1976.

Seven healthy young women, 3 whom had been taking oral contraceptives, were examined during the course of 2 menstrual cycles to assess their isometric strength, their endurance during a series of 5 fatiguing isometric contractions at a tension of 40% MVC, and their blood pressures and heart rates during those fatiguing contractions. Two sets of experiments were performed, one in which the subject's forearm temperature was allowed to vary as a function of T_A, and one with the muscle temperature stabilized by immersion of the forearm in water at 37 degrees C. During exposure to ambient temperatures, isometric strength and both the heart rate and blood pressure responses at rest and at the end of a fatiguing, sustained isometric exercise, were not significantly different during any phase of the menstrual cycle in any subject. In contrast, the isometric endurance in the women not taking oral contraceptives varied sinusoidally in all 5 contractions with a peak endurance midway through the ovulatory phase and the lowest endurance mid-way through the luteal phase of the menstrual cycle. The isometric endurance of the women taking oral contraceptives did not vary during their menstrual cycle. After stabilization of the temperature of the muscles of the forearm in water at 37 degrees C, the isometric endurance of the normal subjects showed a hyperbolic response with the maximal endurance at the beginning and end of their cycles, and the shortest endurance at mid-cycle. Here again, however, the isometric endurance of the women taking oral contraceptives did not vary after immersion of their forearms in the 37 degree C water.

92. **Petrofsky, J. S.; Lind, A. R.**
"Insulative power of body fat on deep muscle temperatures and isometric endurance."
Journal of Applied Physiology. 39(4): 639-642. 1975.

Four male subjects were examined to assess the relationship of body fat content to deep muscle temperature and the endurance of a fatiguing isometric handgrip contraction at a tension set at 40% MVC. Muscle temperature was altered by the immersion of the forearm in water at temperatures varying from 7.5 to 40 degrees C. In all subjects, there was a water bath temperature above and below which isometric endurance decreased markedly; the difference among individuals was solely accounted for by the individual's body fat content. Thus, subjects with higher body fat content required lower bath temperatures to cool the forearm musculature to its optimum temperature, which we found to always be approximately 27 degrees C measured 2 cm perpendicularly to the skin in the belly of the brachioradialis muscle. Further, in one subject, we found that a reduction in this subject's body fat content resulted in a corresponding increase in the water bath temperature necessary to cool his muscles to their optimum isometric performance. The data demonstrate the striking insulative power of the thin layer of fat around the forearm in man in protecting shell tissues from cold exposure.

93. **Pheasant, S. T.**
"Sex differences in strength: Some observations on their variability."
Applied Ergonomics. 14(3): 205-211. 1983.

One hundred and twelve datasets, which allowed a direct comparison of the strengths of men and women, were located in the published literature. For each of these, three indices of sex difference were calculated: the ratio of the mean female strength to the mean male, the proportion of the total variance in strength attributable to sex, and the percentage of chance encounters between members of the opposite sex in which the female is stronger. Sex difference was shown to be variable, the values of these indices being both task and population specific. An experiment was conducted in which male and female subjects gripped and turned knurled cylindrical handles of 10, 30, 50, and 70 mm diameter. Maximum isometric torques were recorded. Sex differences became more pronounced as handle size increased. The optimal handle-size was 50 mm for both males and females. Data concerning whole body exertion were also analyzed for sex differences. It is concluded that similar tests of strength could exhibit very different levels of sex difference. The task or equipment designer should not make assumptions about sex differences in strength for a particular action, but should rely on empirical investigation.

94. **Phillips, M. D.; Bogardt, A.; Pepper, R. L.**
Female and male size, strength and performance: A review of current literature.
Integrated Sciences Corp., Santa Monica, CA, 1981, 159 pp., DTIC#AD-A109 270.

The increase in female personnel utilization aboard ship has initiated a need to examine gender based differences in anthropometrics, biomechanics, psychophysical performance, physiological attributes and the relationship of these factors to the design of shipboard equipment and fittings. Literature in this area was examined by Ayoub et al (1978). The purpose of the present report was to update and extend the baseline established by Ayoub et al (1978) by examining current work. Specifically, this report seeks to:

- consolidate current performance and anthropometric articles into an updated data base,
- identify the presence and degree of overlap between the sexes in performance and anthropometric variables,
- relate gender based differences to potential effects on performance levels,
- identify "gaps" in the anthropometric and performance literature that warrant further investigation.

To accomplish this, a survey of the relevant scientific literature was conducted which focused on male/female differences in basic anthropometrics and performance. The review covered the published literature as well as technical notes and reports that have a limited distribution. The results of a critical review of the obtained literature indicated that several general and specific needs exist which must be addressed in order to increase the utility of this data base for system design applications. The lack of standardized methodologies and the potential discrepancy between laboratory data and job performance were noted. Gaps were noted in the literature concerning gender differences in: psychomotor skills, vigilance, cold tolerance and dynamic anthropometry/biomechanics. More work is recommended to examine the effectiveness of compensatory physical training programs where female performance is found to be below criteria. Additionally, the positive aspects of gender based performance differences need to be further examined and exploited in equipment design and task and function allocations. Gender differences in visual system biases and their potential application to monitoring and detection tasks are noted. Articles examined in this update are classified by a matrix of topic areas to provide cross referencing. Abstracts of the current literature are also included.

95. **Price, S. A.**
Procedural guide to aircrew anthropometric accommodation assessment.
Naval Air Warfare Center/Aircraft Division, Patuxent River, MD. 1993.

NAVAIRSYSCOM (AIR-531) tasked us to investigate and develop new procedures for determining the ranges and limitations of anthropometric accommodation in military aircraft. These procedures quantify what types of aircrew--based on their body's morphologies--are able to safely and efficiently operate a particular crewstation in an operational environment. Aircrew Anthropometric Accommodation Assessment provides detailed, repeatable methods for obtaining the accommodation data needed to determine this. Results are plotted to determine the full range of anthropometric values and their relationship to pilot/aircrew "fit" for a number of important areas. Use of Aircrew Anthropometric Accommodation Assessment enables the establishment of Anthropometric Restriction Codes, reduces the need for fit-checks, guides Student Naval Aviators into appropriate pipelines, determines contractor compliance with design goals, and identifies deficiencies in the crewstation layout of mockups and aircraft undergoing development.

96. **Reilly, R. R.; Zedeck, S.; Tenopyr, M. L.**
"Validity and fairness of physical ability tests for predicting performance in craft jobs."
Journal of Applied Psychology. 64(3): 262-274. 1979.

Problems relating to performance, accidents, and turnover in outdoor telephone craft jobs stimulated two experiments aimed at developing and validating a physical test battery. Based on job analysis results, a battery of nine measures was administered to a sample of 128 subjects (83 males and 45 females) in Experiment 1. A two-test battery (dynamic arm strength and reaction time), valid for predicting job task performance and turnover, was selected. Regression equations for males and females were not significantly different. Experiment 2 included a sample of 210 subjects (132 males and 78 females). A three-test battery consisting of a body density measure, a balance test, and a static strength test was selected based on relationships with training performance. No significant differences were found in the regression equations for males compared to females. The Experiment 2 battery was also significantly related to field performance, training completion, and accidents, and was valid for the Experiment 1 criteria.

97. **Robertson, D. W.; Trent, T.**
Documentation of an occupational strength test battery (STB).
Navy Personnel Research and Development Center, San Diego, Ca.,1985, MPTL TN 86-1.

A strength test battery (STB) was validated on several muscularly demanding occupational tasks of common shipboard and occupation-specific duties. A dynamometer-measured armpull was the best correlate of the STB. An "impact analysis" procedure was also developed so that management could determine the effect of a STB cut-score on the percentage of men or women that would be excluded from entering a particular job.

98. **Robinette, K.; Churchill, T.; McConville, J. T.**
A comparison of male and female body sizes and proportions.
Air Force Aerospace Medical Research Lab, Wright-Patterson AFB, OH, 1979, 28 pp., AFAMRL-TR-79-69.

There has been, in the past few years, an increase in the diversity of occupational positions filled by women in the Air Force and the other military branches. As the opportunities increase, the workplace designer is faced more and more frequently with the problem of accommodating the female. Accompanying this problem is a need for documentation of true differences in body size and proportions between Air Force men and women. This report is an initial attempt at fulfilling this need. Utilizing the 1977 Army study, because it is the only survey in which both military males and females were measured at the same time and place, by the same measurers, and using the same measuring techniques and instruments, this study investigates two basic assumptions about the relationship between male and female body size and proportions. The first is the assumption that a female body size can be represented by scaling down the male body. The second is the assumption that females and males of approximately equal body weight and stature are approximately equal in all other proportions. The results of these investigations serve to pinpoint where differences occur and the magnitude of those differences. This should aid in determining the designs or changes in designs which should be necessary to accommodate the female.

99. **Rock, L. C.**
Report of the study group on USAF female aircrew requirement for life support and protective clothing.
Aeronautical Systems Division, Air Force Systems Command, Wright-Patterson AFB, OH, 1977, 195 pp., DTIC#ASD-TR-77-32.

In May 1976 the ASD Life Support SPO was tasked to review the pilot training program and identify problem areas and/or safety of flight hazards and solutions therefore, which might be generated when women are admitted to the Air Force's pilot training program. The program was divided into three groupings: Near Term: Analysis of the orientation flight program; Mid Term: Analysis of the Undergraduate Pilot Training Program (UPT) which includes T-37 & T-38 flight training; Far Term: Analysis of controls, etc., in aircraft to which the female pilot would be assigned.

100. **Sawka, M. N.; Toner, M. M.; Francesconi, R. P.; Pandolf, K. B.**
"Hypohydration and exercise: Effects of heat acclimation, gender, and environment."
Journal of Applied Physiology. 55(4): 1147-1153. 1983.

The purpose of this study was to examine the effects of heat acclimation and subject gender on treadmill exercise in a comfortable (20 degrees C, 40% rh), a hot-dry (49 degrees C, 20% rh), and a hot-wet (35 degrees C, 79% rh) environment while subjects were hypo or euhydrated. Six male and six female subjects, matched for maximal aerobic power and percent body fat, completed two exercise tests in each environment both before and after a 10-day heat acclimation program. One exercise test was attempted when Ç euhydrated and the other test when hypohydrated (-50% from baseline body weight). In general, no significant ($P > 0.05$) differences were noted between men and women at the completion of exercise for rectal temperature (Tre), mean skin temperature (Tsk), or heat rate (HR) during any of the experimental conditions. Hypohydration was generally found to increase Tre and HR responses as well as to decrease sweat rate values while not altering Tsk responses. In the hypohydration experiments, heat acclimation significantly reduced Tre (0.19 degrees C) and HR (13 beats/min) responses in the comfortable environment, but reduced on HR responses were reduced in the hot-dry (21 beats/min) and hot-wet (21 beats/min) environments. The present findings indicate that men and women respond in a physiologically similar manner to hypohydration during exercise. It is also suggested that an expanded plasma volume, mediated by heat acclimation, may have attenuated Tre and HR responses during hypohydration.

101. **Sawka, M. N.; Young, A. J.; Cadarette, B. S.; Levine, L.; Pandolf, K. B.**
"Influence of heat stress and acclimation on maximal aerobic power."
European Journal of Applied Physiology. 53(4): 294-298. 1985.

Thirteen male volunteers performed cycle ergometer maximal oxygen uptake (VO2max tests) in moderate (21 degrees C, 30% rh) and hot (49 degrees C, 20% rh) environments, before and after a 9-day heat acclimation program. This program resulted in significantly decreased ($P < 0.01$) final heart rate (24 beats/min) and rectal temperature (0.4 degrees C) from the first to last day of acclimation. The VO2max was lower ($P < 0.01$) in the hot environment relative to the moderate environment both before (8%) and after (7%) acclimation with no significant difference ($P > 0.05$) shown for maximal power output (PO max, watts) between environments either before or after acclimation. The VO2max was higher ($P < 0.01$) by 4% after acclimation in both environments. Also, PO max was higher ($P < 0.05$) after acclimation in both the moderate (4%) and hot (2%) environments. The reduction in VO2max in the hot compared to moderate environment was not related to the difference in core temperature at VO2max between moderate and hot trials, nor was it strongly related with aerobic fitness level. These findings indicate that heat stress, per se, reduced the VO2max. Further, the reduction in VO2max due to heat was not affect be state of heat acclimation, the degree of elevation in core temperature, or level of aerobic fitness.

102. **Schafer, E.; Bates, B. T.**
Anthropometric comparisons between body measurements of men and women.
Air Force Aerospace Medical Research Lab, Wright-Patterson AFB, OH, 1982, 83 pp., DTIC#AD-A204 698.

This report documents some of the differences in the body proportions of men and women in the region of the torso and legs. The study utilized discriminate analysis to pinpoint multivariate differences and regression analysis to indicate the magnitude of these differences from an applications' standpoint. The coefficients and estimates from these analyses are presented. It appears that men and women are proportioned so differently that it should be nearly impossible to have a single sizing system for coverall or flight suit types of clothing or equipment.

103. **Schopper, A. W.; Mastroianni, G. R.**
Helicopter-referenced single control, center position force exertion capabilities of males and females.
Army Aeromedical Research Lab, Ft. Rucker, AL, 1985, 60 pp., DTIC#AD-A161 234.

In response to the need for reevaluation of anthropometric criteria contained in the U.S. Army medical standards for flying duty, an assessment was made of helicopter-control referenced force exertion capabilities of a sample of Army males and females. Males (N=74) ranged from 159 cm through 196 cm in stature; females (N=66) ranged from 152 cm through 183 cm. The force-exertion data were compared to values cited in MIL-H-8501A as upper force limits for the design of helicopter controls. The focuses of the analyses were upon the force exertion capabilities of individuals 167 cm (65.7 inches) and below in stature since, by virtue of their relatively small size, they represent the portion of the population which are most apt to evidence inabilities to exert forces which equal or exceed control force design limits. The comparison revealed that, overall, the presently existing limits (published in 1961) for other-than-the normal operational flight envelope exceeded the force exertion capabilities of 10% of the 39 small males evaluated and 27% of the 56 females evaluated. Most failures to achieve existing or proposed control force design limits occurred because of inabilities to attain criterion-level exertion data from the small individuals of this study, various combinations of specific control force design limits were evaluated to develop estimations of overall 'set-wise' failure rates likely to be encountered during possible future strength testing/screening. Because testing entailed no incentive for participation and involved multiple exertions within the session, it is anticipated that the percentage of failures encountered represents an overestimation of the failure-rate which would likely be encountered in the future while testing the strength capability of short individuals actually seeking to become or remain as aviators.

104. **Schopper, A. W.; Mastroianni, G. R.**
Simultaneous multiple control force exertion capabilities of males and females versus helicopter control force design limits.
Army Aeromedical Research Lab, Ft. Rucker, AL, 1987, USAARL 87-14.

Military standards and design guidelines do not consider the potential for degradation in the magnitude of force which can be applied by a crew member or operator as the result of having to perform more than one control input at the same time. In assessing helicopter-control-referenced strength capabilities as a part of an overall program to update medical standards for US Army flying duty, 130 subjects performed maximal voluntary exertions on each of the three primary helicopter controls (cyclic, collective, and pedals). These exertions were undertaken both as separate inputs to single controls and simultaneously executed inputs to all three controls. The findings revealed substantial and significant force degradation occurred during simultaneously executed exertions (relative to the magnitudes of single control exertions). Cyclic inputs were affected least. The degree of force degradation associated with collective and pedal inputs varied with the particular combinations of direction-of-exertion employed. The resulting patterns for force degradation were similar for the collective and pedal with the extent of degradation being larger for the pedal inputs (typically 40-50%) than for the collective inputs (typically 20-35%). Substantial proportions of the subjects (approximately 50% of the males and more than 90% of the females) were unable to consistently attain design-guide force levels (MIL-H-8501A, 1961) on all three controls during all of the 16 simultaneously executed exertions. There exists a need to consider simultaneously executed force inputs in relevant design guides and standards and the probability of an aviator being confronted with those input requirements.

105. **Shannon, R. H.**
Biomechanics analysis of tasks involving manual materials handling.
Naval Biodynamics Lab, New Orleans, LA, 1982, 27 pp., DTIC#AD-A113 955.

Two papers are presented which deal with biomechanics and its relationships with manual materials handling, sex differences and training. The first paper outlines a factor analytic modeling of lifting in the floor-knuckle and knuckle-shoulder regimens under experimental conditions. Sixteen subjects were divided equally into four groups of males trained/untrained and females trained/untrained. Results indicated that (1) there were different motion patterns among the four groups, (2) male movements approximated the trained and female movements approximated the untrained conditions, and (3) trained individuals demonstrated more efficient and coordinated lifts. Training programs are recommended in the working environment if women are expected to lift moderately heavy loads because of their lower physical fitness and coordination when compared to men. This statement is further supported by the second paper, which conducted a critical incident technique of 484 strain/sprain/overexertion injuries of naval civilian government workers. Results indicated that males had significantly more injuries to the back, to craftsmen/operatives/laborers, using heavy/very heavy weight. On the other hand, women showed significantly more incidents to the shoulder/neck/arms, in sales/service/clerical occupations, using light/medium loads. Male incidents seem to be related more to a failure to recognize safety hazards, while female injuries appear to be caused by poor load handling techniques.

106. **Shannon, R. H.**
Determination of efficient methods of lift by comparing trained and untrained male and female lifters.
Naval Biodynamics Lab, New Orleans, LA, 1980, 39 pp., DTIC#AD-A100 349.

The primary objective of this investigation was to analyze the effects of sex and training variables during non-repetitive, short-duration lifts in the sagittal plane. A sample of sixteen subjects (eight men and eight women) were used in the experiment. Selection of these subjects was based on the need to control for size, weight, age and experience. One-half of each sex sub-sample was part of a lifting training program, while the other half was used as control group. The effects of body movements by these subjects in the height ranges from the floor to the knuckle and the knuckle to the shoulder were ascertained with 10, 25, 40 pound weight loads. Data were collected using electromyograms to determine muscular strain, stroboscopic photography to calculate differences in displacement--time vectors, and the force platform to specify force changes at the feet. The data were analyzed using various statistical techniques--factor analysis, regression analysis, analysis of variance, t-test and non-parametric statistics. The results of this effort were a five factor biomechanical model, regression equations predicting inertial forces at the hands, and significant differences between the untrained and trained conditions, and males and females. The overriding conclusion is that manual handling training programs are necessary in the work environment if women are expected to lift loads of approximately 40 pounds.

107. **Shapiro, Y.; Pandolf, K. B.; Avellini, B. A.; Pimental, N. A.; Goldman, R. F.**
"Physiological responses of men and women to humid and dry heat."
Journal of Applied Physiology. 49(1): 1-8. 1980.

Sex-related differences were evaluated in 10 males and 9 females under hot-wet and hot-dry conditions. Pre acclimatized subjects were exposed to a comfortable climate (20 deg C, 40% rh), mild-wet weather (32 deg C, 80% rh), two hot-wet conditions (35 deg C, 90% rh; 37 deg C, 80% rh), and two hot-dry conditions (49 deg C, 20% rh, 54 deg C, 10% rh). Exposures lasted 120 minutes: 10 min rest, 50 min walk (1.34 m/s), 10 min rest, 50 min walk. During hot-dry exposures, heart rate (HR) and rectal temperatures (Tre) were significantly lower for males than females by 13 to 20 beats/min and by 0.25 and 0.32 deg C for the two conditions; no significant differences in sweat loss (msw) were observed. During hot-wet exposures, both mean final Tre and msw were lower in females than males by 0.34 and 0.24 deg C and by 106 and 159 $g/m^2/h$, respectively (males sweated 25 and 40% more than females). None of these differences correlated with maximal O_2 uptake, body weight, skin surface area, or percentage of body fat. During hot-wet exposures, a negative relationship between surface area-to-mass ratio (Ad/wt) and Tre, mean skin temperature, HR, and change in heat storage was found. It was suggested that three major factors are involved in these differences:) higher Ad/wt for females than for males, 2) better sweat suppression from skin wetness for women, and 3) higher thermoregulatory set point for women than for men.

108. **Stanley, S. N.; Taylor, N. A.**
"Isokinematic muscle mechanics in four groups of women of increasing age."
European Journal of Applied Physiology. 66(2): 178-184. 1993.

The purpose of this study was to evaluate the effects of age on dynamic muscle attributes of the knee extensors and flexors in post menopausal women. Young healthy women (3rd decade, n = 15; 4th decade, n = 5) and older healthy women (6th decade, n = 9; 7th decade, n = 6) were tested at six angular velocities from 60 degrees/s to 400 degrees/s. The 3rd and 4th decade groups produced greater extensor and flexor values for strength related variables at all angular velocities (peak torque, angle specific torque, work, power) than both the 6th and 7th decade groups ($P < 0.05$). However, relative changes in these variables, with increments in angular velocity, were equivalent among the groups. Analysis of the flexor: extensor ratios for these variables demonstrated a differential loss in flexor function with increased age, perhaps indicative of type II motor unit loss or muscle fiber atrophy. It is suggested that such changes may be present even within 4th decade subjects.

109. **Staron, R. S.; Karapondo, D. L.; Kraemer, W. J.; Fry, A. C.; Gordon, S. E.; Falkel, J. E.; Hagerman, F. C.; Hikida, R. S.**
"Skeletal muscle adaptations during early phase of heavy-resistance training in men and women."
Journal of Applied Physiology. 76(3): 1247-1255. 1994.

An 8-wk progressive resistance training program for the lower extremity was performed twice a week to investigate the time course for skeletal muscle adaptations in men and women. Maximal dynamic strength was tested biweekly. Muscle biopsies were extracted at the beginning and every 2 wk of the study from resistance-trained and from nontrained (control) subjects. The muscle samples were analyzed for fiber type composition, cross-sectional area, and myosin heavy chain content. In addition, fasting blood samples were measured for resting serum levels of testosterone, cortisol, and growth hormone. With the exception of the leg press for women (after 2 wk of training) and leg extension for men (after 6 wk of training), absolute and relative maximal dynamic strength was significantly increased after 4 wk of training for all three exercises (squat, leg press, and leg extension) in both sexes. Resistance training also caused a significant decrease in the percentage of type IIb fibers after 2 wk in women and 4 wk in men, an increase in the resting levels of serum testosterone after 4 wk in men, and a decrease in cortisol after 6 wk in men. No significant changes occurred over time for any of the other measured parameters for either sex. These data suggest that skeletal muscle adaptations that may contribute to strength gains of the lower extremity are similar for men and women during the early phase of resistance training and, with the exception of changes in the fast fiber type composition, that they occur gradually.

110. **Stauffer, R. W.; McCarter, M.; Campbell, J. L.; Wheeler, L. F. J.**
"Comparison of metabolic responses of United States Military Academy men and women in acute military load bearing."
Aviation, Space and Environmental Medicine. 58(11): 1047-1056. 1987.

Twenty-four first year United States Military Academy (USMA) men and women were studied to compare metabolic response differences in seven horizontal walking velocities, under three military load bearing conditions. The treadmill protocol consisted of walking or jogging on a horizontal treadmill surface for 3-min intervals at velocities of 3, 3.5, 4, 4.5, 5, 5.5, and 6 mph. The three military load bearing conditions weighed 5, 12, and 20 kg. Metabolic measurements taken at each speed in each of the military load bearing conditions were: minute volume, tidal volume, respiratory rate, absolute and relative to body weight oxygen consumption, and respiratory quotient. Two three-way analyses of variance for repeated measures tests with main effects of gender, military load, and speed revealed that USMA men and women metabolically respond to different military load bearing conditions; they metabolically respond to different walking and jogging velocities under military load bearing conditions; and they have identifiable and quantifiable metabolic response differences to military load bearing. This study was designed to improve USMA physical and military training programs by providing information to equally and uniformly administer the USMA Doctrine of Comparable Training to men and women alike; and additionally to clarify the "...minimal essential adjustments...required because of physiological differences between male and female individuals ..." portion of Public Law 94-106 providing for the admission of women to America's Service Academies.

111. **Stevenson, J. M.; Deakin, J. M.; Andrew, G. M.; Bryant, J. T.; Smith, J. T.; Thomson, J. M.**
"Development of physical fitness standards for Canadian Armed Forces older personnel."
Canadian Journal of Applied Physiology. 19(1): 75-90. 1994.

The purpose of the study was to develop a minimum physical fitness standard for Canadian Forces personnel, 35 years and older, based on common criteria for physically demanding tasks. A random sample of 100 men and 76 women performed the Exercise Prescription (EXPRES) test and five physically demanding tasks that simulate common military tasks, while restricted, for safety reasons, to 90% maximal predicted heart rate. Results indicated poor predictive power, as variances ranged from 5 to 55% between EXPRES fitness scores and task performance. With approval from an expert panel, the 75th percentile score for each task was selected as the cutting criterion. The passing-group data were converted to Z-scores in order to determine the 5th percentile from each EXPRES item: these scores became the EXPRES fitness standard. The minimum fitness standard had a greater impact on women than on men but was representative of the passing groups for both sexes.

112. **Stobbe, T. J.**
"A test-retest criterion for isometric strength testing."
Proceedings of the Human Factors Society. 455-459. 1984.

Isometric strength testing has commonly been used to evaluate human strength capability. Recently it has been proposed by NIOSH as a form of administrative control for injury prevention. Historically, the number of trials used for each person-test combination has been arbitrarily selected and is often undocumented. This paper proposes a criterion for isometric testing and reports some results using this criterion.

113. **Su, C. Y.; Lin, J. H.; Chien, T. H.; Cheng, K. F.; Sung, Y. T.**
"Grip strength in different positions of elbow and shoulder."
Archives of Physical Medicine Rehabilitation. 75(7): 812-815. 1994.

This study investigated the effect of shoulder position on grip strength in 80 men and 80 women. A Jamar dynamometer was used to measure the grip strength in the four testing positions. The four hand strength tests consisted of three positions in which the elbow was maintained in full extension combined with varying degrees of shoulder flexion (i.e., 0 degrees, 90 degrees, and 180 degrees) and of one position in which the elbow was flexed at 90 degrees with the shoulder in 0 degrees of flexion. Only the dominant hand was tested. The highest mean grip strength measurement was recorded when the shoulder was positioned at 180 degrees of flexion with elbow in full extension; whereas the position of 90 degrees elbow flexion with shoulder in 0 degrees of flexion had the lowest grip strength score. In addition, the grip strength measured with the elbow in extension, regardless of shoulder position (i.e., 0 degrees, 90 degrees, and 180 degrees of flexion), was significantly higher than when the elbow was flexed at 90 degrees with the shoulder positioned at 0 degrees of flexion. Finally, grip strength differed significantly for both sexes and for each age group. The grip values of the standardized 90 degrees elbow flexed position were further analyzed to determine the average performances in the study population. For men, grip strength peaked within the 20 to 39 years age group and gradually declined thereafter. For women, the highest mean grip strength measurement was recorded in the 40- to 49-year-old age group and then deteriorated with age. The findings are valuable in the evaluation and rehabilitation training of hand injured patients.

114. **Surburg, R. R.; Williamson, C. B.**
A study to establish physical fitness norms for female aviators.
University of West Florida, Pensacola, FL. 1974.

115. **Tesch, P. A.; Hjort, H.; Balldin, U. I.**
"Effects of strength training on G tolerance."
Aviation, Space and Environmental Medicine. 54(8): 691-695. 1983.

The G tolerance of pilots flying modern, high-performance fighter aircraft is crucial. Therefore, methods to increase G tolerance are of vital importance. In this study, G tolerance was studied in a human centrifuge using simulated aerial combat maneuvers (ACM)--consisting of 15-s periods of 4.5 and 7 G until exhaustion--before and after 11 weeks of muscle strength training. The ACM-time in 11 fighter pilots was increased after this training by 39%. Gains were observed in knee extensor muscle strength during slow contractions by 17% and in anaerobic power by 14%. Aerobic performance and various muscle histochemical indices, as assessed from muscle biopsy samples obtained from m. vastus lateralis, were unchanged. Neuromuscular adaptation seems to be responsible for the increased muscle strength, as well as for the improved performance of the M-1 straining maneuver. This might explain the enhanced G tolerance.

116. **Teves, M. A.**
Using research to match the soldier to the job.
Army Research Institute of Environmental Medicine, Natick, MA, 1984, 9 pp., DTIC#AD-A136 492.

The study consisted of three MEPSCAT battery administrations. Phase one--Pre-Basic Training evaluation was performed on 980 male and 1000 female new recruits at Ft. Jackson, SC during September and October, 1982. Phase two--Post-Basic Training evaluation was a subsample of the original group consisting of 90 males and 110 females. The purpose of Phase two was to examine changes in fitness levels following 7 weeks of Basic Training. Phase three--Post-Advanced Individual Training evaluation was administered to 470 males and 485 females who were members of the original Phase one group. In order to perform the Phase three testing, the USARIEM Exercise Physiology Division personnel were required to test at four different Army posts simultaneously. The AIT posts included were Ft. Jackson, SC, Ft. Gordon, GA, Ft. Lee, VA and Ft. Sam Houston, TX. During phase three, a series of performance tasks was administered to the same soldiers. These performance tasks were designed to represent the true demands of the MOS categories. The Army Research Institute (ARI) was charged with the collection and analysis of the performance task data. The performance tasks involved lifting, pushing, pulling, carrying and torque tasks. After careful comparison of MEPSCAT battery scores and performance task scores, ARI found the Incremental Dynamic Lift test to be the best test item to use to match individual capacity to the performance of the MOS related job tasks. This recommendation has received careful scrutiny and review and has been approved at all levels within the Army as well as the Office of the Secretary of Defense. A three year longitudinal follow up study will be performed by an army advisory group to determine the effectiveness of the MEPSCAT screening system in reducing work related injuries and improving the quality of job performance.

117. **Teves, M. A.; Vogel, J. A.; Wright, J. E.**
Comparison of male and female maximum lifting capacity.
Army Research Institute of Environmental Medicine, Natick, MA, 1985, 15 pp., DTIC#AD-A180 687.

A large influx of women into traditionally male fields of employment has drawn much attention to the strength differences between men and women. Two tests of isometric strength (handgrip and upright pull) and two tests of maximum lift capacity (a weight lift machine-IDL 152 and a weighted box lift MLC 132) were administered to 90 male and 107 female soldiers at the end of their Basic Training in order to examine the differences in female/male (F/M) strength ratio. Skinfold measurements were made to obtain an estimate of lean body mass (LBM). Females exhibited 63% of the isometric strength and 55-59% of the lifting capacity of males. When the scores were normalized for body weight (BW), females were 75% as strong as males on isometric measures, and were able to lift 66% as much on IDL 152 and 72% as much on MLC 132. When normalized for LBM the F/M ratio improved to 86% for isometric strength, 75% for IDL 152 and 82% on MLC 132. It is apparent that a number of factors, other than LBM, are responsible for gender differences in strength. Comparison of the two lifting tasks revealed that on the average, males were able to lift 18% more weight and females 24% more weight on the free lift than on the machine lift. This would suggest that if a machine lift is used for pre-employment screening purposes, the absolute weight an applicant is required to lift on the machine need not equal the maximum weight to be lifted on the job. As the difference between a machine lift and a free lift task was greater in females, a machine lift test may pose a greater disadvantage to female candidates than would isometric or free weight lift testing.

118. **Torsani-Fatkin, L. L.; Hudgens, G. A.**
Human performance: More psychological and physiological sex differences (A selected bibliography).
Human Engineering Lab, Aberdeen Proving Ground, MD, 1982, 205 pp., DTIC#AD-A147 522.

The bibliography, a supplement of Hudgens and Torsani-Fatkin (1980), is a compilation of 1891 references dealing with, or related to, the effects of sex differences on human performance. Four major categories are defined: An Overview of Sex Differences, Physiological Sex Differences, Sex Differences in Cognitive and Motor Abilities, and Sex Differences in Personality. While emphasis is on literature published in the period 1979-1981, many earlier works omitted from the 1980 bibliography are included. An index of first authors is provided.

119. **Vogel, J. A.**
"Gender differences in physical exercise capacity."
Presidential Commission on the Assignment of Women in the Armed Forces Scientific Proceedings. 1992.

120. **Vogel, J. A.; Wright, J. E.; Patton, J. F. III**
Development of new gender-free physical fitness standards for the Army.
Army Research Institute of Environmental Medicine, Natick, MA, 1980, 15 pp., DTIC#AD-A090 445.

121. **Vogel, J. A.; Wright, J. E.; Patton, J. F. III; Dawson, J.; Eschenback, M. P.**
A system for establishing occupationally-related gender-free physical fitness standards.
Army Research Institute of Environmental Medicine, Natick, MA, 1980, 25 pp., DTIC#AD-A094 518.

The Army's desire to utilize greater numbers of women in physically demanding, non-traditional occupations has created the need to match individual capacities with occupational demands. Research has been conducted to develop a process by which objectively determined physical demands of MOSs can be converted into gender-free physical fitness standards. These standards could then be used both for MOS assignment qualification as well as assuring maintenance of fitness commensurate with job demands. The process was initiated by compiling individual task lists from which clusters of MOSs were formed of those with similar physical demands. The most demanding MOS tasks within each cluster were then measured for their actual physiological cost, force required and/or energy expended, with these costs then being converted into equivalent physiological capacities. These capacities were expressed in terms of muscle strength and aerobic power (stamina) which can be assessed at the time of entrance into the service as well as during periodic on-the-job evaluations. This research has resulted in the derivation of five sets of standards, encompassing three levels of demand within two categories of fitness (strength and stamina). The process describes a system by which physically demanding occupations can be assigned on a gender-free basis which will be scientifically defensible.

122. **Wagner, J. A.; Miles, D. S.; Horvath, S. M.**
"Physiological adjustments of women to prolonged work during acute hypoxia."
Journal of Applied Physiology. 49(3): 367-373. 1980.

Five women (23-32 yr) performed bicycle work in a hypobaric chamber for 2 h at 41% of their respective altitude maximal oxygen uptakes (VO2) at 758, 586, 523, and 446 Torr barometric pressures (PB). Steady-state VO2 was achieved within 5 min work at all altitudes. Pulmonary ventilation (29.2 $\pm$ 1.9 (mean $\pm$ SE) 1/min, BTPS), respiratory rate (22 $\pm$ 2 breaths/min), cardiac output (8.5 $\pm$ 1.4 1/min), heart rate (115 $\pm$ 6 beats/min), and stroke volume (75 $\pm$ 13 ml) were similar at all altitudes, but time-related changes differed with altitude. Blood lactates did not change with work duration and were similar at 758 and 586 Torr PB but progressively elevated at 523 and 446 Torr. Blood norepinephrine, measured only at 758 and 446 Torr PB, increased with work but not altitude; epinephrine increased only at altitude. Norepinephrine levels and respiratory, cardiovascular, and thermoregulatory functions were essentially dependent on relative work load; blood lactates and epinephrine levels were not. Many physiological functions in these women performing sustained light work during acute altitude exposure were remarkably stable in contrast to previously reported studies on men.

123. **Wagner, J. A.; Miles, D. S.; Horvath, S. M.; Reyburn, J. A.**
"Maximal work capacity of women during acute hypoxia."
Journal of Applied Physiology. 47(6): 1223-1227. 1979.

Six healthy women (22-34 yr of age) performed maximal bicycle work in a hypobaric chamber at sea level and at simulated altitudes of 2,130 and 3,050 m (barometric pressures, 758, 586, and 523 Torr). Maximal oxygen uptake (VO_2max) decreased 10 and 15% from sea-level values at 2,130 and 3,050 m, respectively. At these altitudes minute ventilation (VEBTPS) increased 17 and 22% respectively, a consequence of increased respiratory rate (fR). Respiratory exchange ratios increased 10 and 14%, and oxygen pulse decreased 9 and 12%, respectively, at 2,130 and 3,050 m. Maximal blood lactates, heart rates, cardiac outputs, and plasma volume shifts were unaffected by these altitudes. Although during maximal work the percentage increases in VEBTPS, fR, and R that resulted from altitude exposure were greater in women than those previously reported for men, the decrements in VO_2max were comparable to those in men. The results show that relative to their performance at sea level, men and women have equal ability to perform maximal work at altitudes up to 3,050 m.

124. **Walamies, M.; Turjanmaa, V.**
"Assessment of the reproducibility of strength and endurance handgrip parameters using a digital analyser."
European Journal of Applied Physiology. 67(1): 83-86. 1993.

A group of 40 healthy individuals (27 women and 13 men) participated in a handgrip test and were retested 1-2 months later. A strain-gauge sensor with a digitised signal and computerized printout was used. A 5-s maximal squeeze test was first made three times, followed by one endurance test with 45%-55% power of the maximal value. The best maximal value was most often (42%) achieved in the third (initial test) or second (retest) attempt. The reproducibility of maximal value was very good; the Pearson correlation coefficient between initial test and retest (r = 0.98) was even slightly higher than in studies with older analogue instruments. The difference of maximal values [361 (SD 109) N, initial test and 368 (SD 110) N, retest] was insignificant. A moderate 12% long-term change in maximal value was statistically significant. Reproducibility of the power factor (integrated area of power with time) was also very good in this short test, correlating closely (r = 0.98-0.99) with the maximal value. Other indexes (grip rate, fatigue percentage and relaxation rate) were not stable enough to be practical. Endurance results were somewhat variable (r = 0.73), which implied in the main variable motivation. Only marked changes of over 50% in endurance were statistically significant. Endurance power increased significantly in the retest, which, in spite of an r-value of 0.82, would make its use in a follow-up study difficult. We found the computer-based handgrip test both precise and practical in assessing maximal voluntary strength; endurance was more difficult to reproduce.

125. **Walsh, C. A.; Graham, T. E.**
"Male-female responses in various body temperatures during and following exercise in cold air."
Aviation, Space and Environmental Medicine. 57(10 Pt 1): 966-973. 1986.

During cold exposure women have lower skin temperatures on the trunk and legs. This study evaluated whether these colder temperatures were also manifested in peripheral sites (nose, chin, and finger) where frost bite often occurs. In addition, the core temperature responses to passive rewarming were studied to evaluate whether women experience greater afterdrop as a result of colder shell temperatures. The subjects, eight males (M) and eight females (F), were tested on four occasions, once each at +10, +3.5, -3.5, and -10 degrees C. Each day the subject, clothed in sweat clothes and coveralls, performed 6 bouts of intermittent exercise (20 min. exercise (60W), 10 min. rest) for 3 h in the designated temperature and then rested in +21 degrees C for 1 h. The F had lower Tsk in every test, but finger, nose, and chin temperatures were never lower in F. There were no M-F differences in core temperature during cold exposure or during recovery, even though the Tsk would predict that F had a colder shell. Furthermore, there was no apparent relationship between Tsk rewarming and changes in T core. The data demonstrated no M-F differences in potential for either frost bite or for afterdrop in core temperature.

126. **Wardle, M. G.**
"Women's physiological reactions to physically demanding work."
Psychology of Women Quarterly. 1(2): 151-159. 1976.

Eight females (mean age 20 yrs) were subjects in an experiment consisting of two parts. The first part measured the maximal work capacity and peak work load on a treadmill at a speed of 8 kms (5 mph) with grade increasing 2.5% every 3 min. The second part measured energy expended on a treadmill walked under varying conditions of speed, grade, and load in an eight hour day of strenuous work. The results showed that these women were able to do strenuous work expending 2369 kcals for 8.5 hrs. The energy expended exceeded that required for most physically demanding occupations. The results have implications for vocational choice research for women who have been excluded from occupations due to an assumed lack of strength.

127. **Washburn, R. A.; Seals, D. R.**
"Peak oxygen uptake during arm cranking for men and women."
Journal of Applied Physiology. 56(4): 954-957. 1984.

To determine upper body peak O_2 uptake (VO_2) in a group of young females and to obtain information on possible sex differences, 40 subjects, 20 females and 20 males, mean age 26 ± 4 (SD) and 31 ± 6 yr, respectively, were studied during maximal arm-cranking exercise. Peak values for power output, VO_2, minute ventilation (VE), and heart rate (HR) were determined for each subject. In addition, arm-shoulder volume (A-SV) was measured before exercise. Significant differences between males and females ($P < 0.05$) were found for peak power output (134 ± 18 vs. 86 ± 13 W), peak VO_2 expressed in liters per minute (2.55 ± 0.45 vs. 1.81 ± 0.36) and milliliters per kilogram per minute (34.2 ± 5.3 vs. 29.2 ± 4.9), peak VE (95.4 ± 14.5 vs. 70.1 ± 19.2 1/min), and A-SV ($3{,}126 \pm 550$ vs. $2{,}234 \pm 349$ ml), whereas peak HR was not significantly different between the two groups (174 ± 14 vs. 174 ± 36 beats/min). However, when peak VO_2 was corrected for arm and shoulder size there was no significant difference between the groups (0.82 ± 0.13 vs. 0.78 ± 0.13 ml/ml A-SV/min). These results suggest that the observed differences between men and women for peak VO_2 elicited during arm cranking when expressed in traditional terms (1/min and ml/kg/min) are a function of the size of the contracting muscle mass and are not due to sex-related differences in either O_2 delivery or the O_2 utilization capacity of the muscle itself.

128. **Weigmann, J. F.; Burns, J. W.**
Current concepts in female acceleration research.
Washington, DC., 1992, Presidential Commission on the Assignment of Women in the Armed Forces Scientific Proceedings.

Previous research to assess the female physiologic response to acceleration has been primarily associated with low-G centrifugation. While few data are available to describe female +Gz tolerance at levels >+7Gz, there are no published data that describe female tolerance to sustained (>15s) +Gz exposure at these levels. Studies in high, sustained acceleration often include use of a simulated aerial combat maneuver centrifuge profile (SACM) that alternates 15s plateaus of +4.5 and +7 Gz, or 10s plateaus associated with a well-fitted anti-G suit, efficient anti-G straining maneuver technique, increased muscular strength, and sufficient anaerobic capacity. The Flight Motion Effects Branch, Armstrong Laboratory (AL), has therefore implemented a series of research studies using the AL centrifuge to investigate female +Gz duration tolerance relative to male +Gz duration tolerance, physical training state (i.e., strength, anaerobic and aerobic capacity), and anti-G suit fit and effectiveness. Although mean gender differences in some physical characteristics suggest that females, as a population, may be at a disadvantage during sustained +Gz, the same +Gz tolerance standards should be applied to each individual pilot, regardless of gender.

129. **Wheeler, D. L.; Graves, J. E.; Miller, G. J.; O'Connor, P.; MacMillan, M.**
"Functional assessment for prediction of lifting capacity."
Spine. 19(9): 1021-1026. 1994.

OBJECTIVE. This study investigated the ability to predict maximal functional lifting capacity from peak isometric lumbar extension torque and sub maximal lifting mechanics. METHODS. Peak isometric lumbar extension torques were measured on 26 healthy men and women, ages 18 to 39 years. In addition, their lifting mechanics were evaluated while they lifted a sub maximal load. Each subject's maximal lifting capacity (kg) then was predicted from the peak torque and sub maximal kinetic analysis using a linear regression model. RESULTS. Mean values for the predicted and actual maximum weight the subjects lifted were not significantly different (50.3 ± 15.6 kg and 48.5 ± 17.0 kg, respectively, $P \geq 0.05$). The correlation between predicted and criterion values was high ($r = 0.96$), and the total error of the prediction was 5.1 kg, which represented 10.5% of the actual maximum value. CONCLUSIONS. This multi-faceted functional assessment model involving biomechanical analysis of a sub maximal lift and maximal isometric lumbar extension strength accurately predicted a subject's maximum functional lifting capacity.

130. **Whinnery, A. M.; Whinnery, J. E.**
"The electrocardiographic response of females to centrifuge +Gz stress."
Aviation, Space and Environmental Medicine. 61(11): 1046-1051. 1990.

Women continue to expand their participation in all areas of aviation, including flying high performance fighter aircraft. Acceleration (+Gz) stress is unique to fighter aviation, therefore it is important to thoroughly understand the (ECG) response to +Gz stress since it reflects a portion of the cardiovascular +Gz tolerance. A comparison of the ECG response to centrifuge +Gz stress between 685 men and 94 women was made from data existing within a centrifuge data repository. The frequency of occurrence of specific types of atrial, ventricular, and the other most frequently observed ECG changes to +Gz were compared for females and males. Females had less atrial ectopy; essentially equivalent premature ventricular contractions (PVC's), multiformed PVC's, paired PVC's; less frequent ventricular and supraventricular tachycardia; and more frequent PVC's in a bigeminal pattern and QRS on T PVC's. Sinus arrythmia, sinus bradycardia, and increased T-waves post +Gz stress were more frequent in males, with ectopic atrial rhythm and atrioventricular dissociation essentially equivalent in males and females. Although few women have participated in either simulated aerial combat maneuver type centrifuge profiles or centrifuge high-G training, they have shown similar ECG changes including conduction and rhythm disturbances infrequently seen in males, such as +Gz-induced right bundle branch block and high-G bradycardia. Based on the currently available ECG response data, women have no demonstrated unique susceptibility to +Gz-induced ECG changes. Therefore, no contraindication exists to initiating additional acceleration research to fully evaluate women's tolerance to the more stressful, higher levels of +Gz stress.

131. **Whitley, P. B.**
"U.S. Navy experience with females during acceleration research and G-tolerance training."
Presidential Commission on the Assignment of Women in the Armed Forces Scientific Proceedings. 1992.

From the limited U.S. Navy experience with females in Anti-G Straining Maneuver Training and as experimental subjects, no differences were found in G-level tolerance or the ability to perform the anti-G straining maneuver.

Females have participated in the same experiments and used the same, advanced, experimental equipment without any gender specific problems.

132. **Woodhead, A. B.; Moynihan, M. E.**
"The effect of Aviation Officer Candidate's School on aerobic and anaerobic fitness."
Military Medicine. 159 (2): 118-120. 1994.

The purpose of this study was to determine the effect of Aviation Officer's Candidate School (AOCS) on the aerobic and anaerobic fitness of the candidates. Thirty candidates were tested prior to and post-AOCS. Anaerobic measures included vertical jump and seated shot-put throw. A 1.5-mile run was used as an aerobic measure. Timed pushups and sit-ups were used as overall strength and endurance measures. Body fat was assessed by OPNAV 6110.1 standards. Statistically significant increases were achieved in all areas, except body fat and push-ups, which produced no significant changes.

133. **Wright, J. E.; Sharp, D. S.; Vogel, J. A.; Patton, J. F. III**
Assessment of muscle strength and prediction of lifting capacity in U.S. Army personnel.
Army Research Institute of Environmental Medicine, Natick, MA, 1984, 46 pp., DTIC#AD-A148 846.

The purpose of this study was to determine muscular strength tests which would be appropriate for Army occupational selection and predictive of job lifting and lifting-carrying tasks. A maximum lift to 132 cm, dead-lift to knuckle height and a short-term self-paced maximal lift-and-carry were utilized as criterion tasks. Isometric strength measures evaluated as predictors included: handgrip, knee extension, trunk extension, upper torso arm-shoulder pull down, standing upward pull at 38 cm and 132 cm height. Dynamic strength of the trunk extensors were also measured with an isokinetic dynamometer. Studies employed both male and female soldiers. Initial analysis selected six isometric strength measures plus lean body mass as potential predictors of the best criterion variable, maximum lift capacity to 132 cm (MSLC). Males and females formed separate populations (non-coincidence) in these measures so that gender could be represented by a numerical designator as a constituent variable in a single predictive equation. Handgrip, 38 cm upright pull and upper torso pull down gave similar predictive power. Ridge regression techniques were utilized to compensate for multicollinearity effects among these predictors. This analysis and operational considerations reduced the final variables to the 38 cm upright pull, lean body mass and gender. For lift capacity to 132 cm, the equation derived was MSLC = -8.466 + 0.9933 (LBM) + 0.006349 (UP 38) - 4.777 (SEX) with males =1 and females =2 for SEX, resulting in a multiple correlation coefficient of 0.89. Median performances for males and females for MSLC was 57.1 kg and 31.1 kg, respectively. Males could lift 1.8 times more than females, but their isometric strength was only 1.5-1.6 times that of females.

134. **Zehner, G. F.; Meindl, R. S.; Hudson, J. A.**
A multivariate anthropometric method for crew station design.
Armstrong Laboratory, Crew Systems Directorate, Wright-Patterson AFB, OH, 1993, 40 pp., AS-TR-1993-0054.

Body size accommodation in USAF cockpits is still a significant problem despite all the years of experience and the many aircraft designs that have been developed. Adequate reach to controls, body clearances (particularly during escape), and vision (internal and external), are all functions of pilot body size and position in the cockpit.
One of the roots of this problem is the way cockpit accommodation is specified and tested. For many years the percentile pilot has been used. This paper describes the errors inherent in the "percentile man" approach, and presents a multivariate alternative for describing the body size variability existing in a given flying population. A number of body size "representative cases" are calculated which, when used properly in specifying, designing, and testing new aircraft, should ensure the desired level of accommodation.

SUBJECT INDEX

121. **Vogel, J. A.; Wright, J. E.; Patton, J. F. III.; Dawson, J.; Eschenback, M. P**. A system for establishing occupationally-related gender-free physical fitness standards.

ISOLATED MUSCLE GROUP TESTING

13. **Balldin, U. I.; Myhre, K.; Tesch, P. A.; Wilhelmsen, U.; Andersen, H. T**. Isometric abdominal muscle training and G tolerance.

31. **Christ, C. B.; Boileau, R. A.; Slaughter, M. H.; Stillman, R. J.; Cameron, J**. The effect of test protocol instructions on the measurement of muscle function in adult women.

52. **Griffin, J. W.; Tooms, R. E.; vander Zwaag, R.; Bertorini, T. E.; O'Toole, M. L**. Eccentric muscle performance of elbow and knee muscle groups in untrained men and women.

53. **Hickson, R. C.; Hidaka, K.; Foster, C**. Skeletal muscle fiber type, resistance training, and strength-related performance.

61. **Kannus, P.; Beynnon, B**. Peak torque occurrence in the range of motion during isokinetic extension and flexion of the knee.

68. **Kues, J. M.; Rothstein, J. M.; Lamb, R. L**. The relationships among knee extensor torques produced during maximal voluntary contractions under various test conditions.

75. **Mayer, F.; Horstmann, T.; Rocker, K.; Heitkamp, H. C.; Dickhuth, H. H**. Normal values of isokinetic maximum strength, the strength/velocity curve, and the angle at peak torque of all degrees of freedom in the shoulder.

80. **Miller, A. E.; MacDougall, J. D.; Tarnopolsky, M. A.; Sale, D. G**. Gender differences in strength and muscle fiber characteristics.

91. **Petrofsky, J. S.; LeDonne, D. M.; Rinehart, J. S.; Lind, A. R**. Isometric strength and endurance during the menstrual cycle.

92. **Petrofsky, J. S.; Lind, A. R**. Insulative power of body fat on deep muscle temperatures and isometric endurance.

108. **Stanley, S. N.; Taylor, N. A**. Isokinematic muscle mechanics in four groups of women of increasing age.

109. **Staron, R. S.; Karapondo, D. L.; Kraemer, W. J.; Fry, A. C.; Gordon, S. E.; Falkel, J. E.; Hagerman, F. C.; Hikida, R. S**. Skeletal muscle adaptations during early phase of heavy-resistance training in men and women.

PHYSIOLOGICAL GENDER DIFFERENCES - GENERAL

4. **Arciero, P. J.; Goran, M. I.; Poehlman, E. T**. Resting metabolic rate is lower in women than in men.

9. **Avellini, B. A.; Kamon, E.; Krajewski, J. T**. Physiological responses of physically fit men and women to acclimation to humid heat.

10. **Avellini, B. A.; Shapiro, Y.; Pandolf, K. B.; Pimental, N. A.; Goldman, R. F**. Physiological responses of men and women to prolonged dry heat exposure.

14. **Barnes, W. S.; Hasson, S. M.; Gadberry, W. L.; Henrich, T. W.; Fang, C.-L**. Absolute and relative power output in men and women.

17. **Billingsley, P. A.; Hudgens, G. A**. Human performance: Sex differences and the influence of the menstrual cycle (A selected bibliography).

18. **Braith, R. W.; Graves, J. E.; Leggett, S. H.; Pollock, M. L**. Effect of training on the relationship between maximal and sub maximal strength.

26. **Canine, M. K.; Derion, T.; Heaney, J. H.; Pozos, R**. An annotated bibliography of heat tolerance: Regarding gender differences.

30. **Charles, M. T**. Women in policing: The physical aspect.

36. **Drinkwater, B. L**. Women and exercise: Physiological aspects.

37. **Drinkwater, B. L.; Folinsbee, L. J.; Bedi, J. F.; Plowman, S. A.; Loucks, A. B.; Horvath, S. M**. Response of women mountaineers to maximal exercise during hypoxia.

38. **Drinkwater, B. L.; Kramar, P. O.; Bedi, J. F.; Folinsbee, L. J**. Women at altitude: Cardiovascular responses to hypoxia.

39. **Dusik, L. A.; Menard, M. R.; Cooke, C.; Fairburn, S. M.; Beach, G. N**. Concurrent validity of the ERGOS work simulator versus conventional functional capacity evaluation techniques in a workers' compensation population.

43. **Evans, W. J.; Winsmann, F. R.; Pandolf, K. B.; Goldman, R. F**. Self-paced hard work comparing men and women.

48. **Frye, A. J.; Kamon, E**. Responses to dry heat of men and women with similar aerobic capacities.

52. **Griffin, J. W.; Tooms, R. E.; vander Zwaag, R.; Bertorini, T. E.; O'Toole, M. L**. Eccentric muscle performance of elbow and knee muscle groups in untrained men and women.

53. **Hickson, R. C.; Hidaka, K.; Foster, C**. Skeletal muscle fiber type, resistance training, and strength-related performance.

57. **Hudgens, G. A.; Torsani-Fatkin, L. L**. Human performance: Psychological and physiological sex differences (A selected bibliography).

67. **Kroll, W.; Kilmer, W. L**. Coordination mechanism in fast human movements--Experimental and modeling studies. Volume 2.

69. **Laubach, L. L**. Comparative muscular strength of men and women: A review of the literature.

84. **Murphy, M. M.; Patton, J. F.; Frederick, F. A**. Comparative anaerobic power of males and females.

85. **Myrsten, A. L.; Lundberg, U.; Frankenhaeuser, M.; Ryan, G.; Dolphin, C.; Cullen, J**. Sex-role orientation as related to psychological and physiological responses during achievement and orthostatic stress.

87. **Pandolf, K. B.; Cain, W. S**. Constant effort during static and dynamic muscular exercise.

88. **Pandolf, K. B.; Sawka, M. N.; Shapiro, Y**. Factors which alter human physiological responses during exercise-heat acclimation.

89. **Pandolf, K. B.; Sawka, M. N.; Shapiro, Y**. Physiological differences between men and women in exercise-heat tolerance and heat acclimation.

90. **Petrofsky, J. S.; Burse, R. L.; Lind, A. R**. Comparison of physiological responses of women and men to isometric exercise.

91. **Petrofsky, J. S.; LeDonne, D. M.; Rinehart, J. S.; Lind, A. R**. Isometric strength and endurance during the menstrual cycle.

93. **Pheasant, S. T**. Sex differences in strength: Some observations on their variability.

94. **Phillips, M. D.; Bogardt, A.; Pepper, R. L**. Female and male size, strength and performance: A review of current literature.

98. **Robinette, K.; Churchill, T.; McConville, J. T**. A comparison of male and female body sizes and proportions.

100. **Sawka, M. N.; Toner, M. M.; Francesconi, R. P.; Pandolf, K. B**. Hypohydration and exercise: Effects of heat acclimation, gender, and environment.

101. **Sawka, M. N.; Young, A. J.; Cadarette, B. S.; Levine, L.; Pandolf, K. B**. Influence of heat stress and acclimation on maximal aerobic power.

107. **Shapiro, Y.; Pandolf, K. B.; Avellini, B. A.; Pimental, N. A.; Goldman, R. F**. Physiological responses of men and women to humid and dry heat.

118. **Torsani-Fatkin, L. L.; Hudgens, G. A**. Human performance: More psychological and physiological sex differences (A selected bibliography).

119. **Vogel, J. A**. Gender differences in physical exercise capacity.

122. **Wagner, J. A.; Miles, D. S.; Horvath, S. M**. Physiological adjustments of women to prolonged work during acute hypoxia.

123. **Wagner, J. A.; Miles, D. S.; Horvath, S. M.; Reyburn, J. A**. Maximal work capacity of women during acute hypoxia.

125. **Walsh, C. A.; Graham, T. E**. Male-female responses in various body temperatures during and following exercise in cold air.

126. **Wardle, M. G**. Women's physiological reactions to physically demanding work.

127. **Washburn, R. A.; Seals, D. R**. Peak oxygen uptake during arm cranking for men and women.

PHYSIOLOGICAL GENDER DIFFERENCES - MILITARY

46. **Fischer, M. D.; Wiegman, J. F.; Bauer, D. H**. Female tolerance to sustained acceleration - A retrospective study.

49. **Gillingham, K. K.; Schade, C. M.; Jackson, W. G.; Gilstrap, L. C**. Women's G tolerance.

72. **Lyons, T. J**. Women in the fast jet cockpit--Aeromedical considerations.

77. **McDaniel, J. W**. Male and female capabilities for operating aircraft controls.

86. **Newsom, B. D.; Goldenrath, W. L.; Winter, W. R.; Sandler, H.** Tolerance of females to +GZ centrifugation before and after bedrest.

110. **Stauffer, R. W.; McCarter, M.; Campbell, J. L.; Wheeler, L. F. J.** Comparison of metabolic responses of United States Military Academy men and women in acute military load bearing.

111. **Stevenson, J. M.; Deakin, J. M.; Andrew, G. M.; Bryant, J. T.; Smith, J. T.; Thomson, J. M.** Development of physical fitness standards for Canadian Armed Forces older personnel.

116. **Teves, M. A.** Using research to match the soldier to the job.

128. **Weigmann, J. F.; Burns, J. W**. Current concepts in female acceleration research.

130. **Whinnery, A. M.; Whinnery, J. E**. The electrocardiographic response of females to centrifuge +Gz stress.

131. **Whitley, P. B**. U.S. Navy experience with females during acceleration research and G-tolerance training.

STRENGTH/FITNESS FROM A MILITARY PERSPECTIVE (EXCLUDING AVIATION)

12. **Baldi, K. A**. An overview of physical fitness of female cadets at the military academies.

15. **Bensel, C. K.; Fink, D. S.; Mellian, S. A**. The psychomotor performance of men and women wearing two types of body armor.

16. **Bielenda, C. C.; Knapik, J.; Wright, D. A**. Physical fitness and cardiovascular disease risk factors of female senior U.S. military officers and federal employees.

33. **Cote, R. W. III.; Bomar, J. B. J.; Robertshaw, G. E.; Thomas, J. C**. Maximal aerobic power in women cadets at the U.S. Air Force Academy.

35. **Daniels, W. L.; Kowal, D. M.; Vogel, J. A.; Stauffer, R. M**. Physiological effects of a military training program on male and female cadets.

40. **Dyer, F. N.; Burke, W. P**. Prediction of success in Airborne training.

58. **Hudgens, G. A.; Torsani-Fatkin, L. L**. Male and female performance on military related tasks.

60. **Johnson, D. M**. Navy job-related male-female differences: Annotated bibliography.

74. **Marriott, B. M.; Grumstrup-Scott, J**. Body composition and physical performance.

77. **McDaniel, J. W**. Male and female capabilities for operating aircraft controls.

79. **McDonald, D. G.; Beckett, M. B.; Hodgdon, J. A**. Psychological predictors of physical performance and fitness in U.S. Navy personnel.

103. **Schopper, A. W.; Mastroianni, G. R**. Helicopter-referenced single control, center position force exertion capabilities of males and females.

104. **Schopper, A. W.; Mastroianni, G. R**. Simultaneous multiple control force exertion capabilities of males and females versus helicopter control force design limits.

105. **Shannon, R. H**. Biomechanics analysis of tasks involving manual materials handling.

106. **Shannon, R. H**. Determination of efficient methods of lift by comparing trained and untrained male and female lifters.

110. **Stauffer, R. W.; McCarter, M.; Campbell, J. L.; Wheeler, L. F. J**. Comparison of metabolic responses of United States Military Academy men and women in acute military load bearing.

111. **Stevenson, J. M.; Deakin, J. M.; Andrew, G. M.; Bryant, J. T.; Smith, J. T.; Thomson, J. M**. Development of physical fitness standards for Canadian Armed Forces older personnel.

116. **Teves, M. A**. Using research to match the soldier to the job.

120. **Vogel, J. A.; Wright, J. E.; Patton, J. F. III.** Development of new gender-free physical fitness standards for the Army.

121. **Vogel, J. A.; Wright, J. E.; Patton, J. F. III; Dawson, J.; Eschenback, M. P**. A system for establishing occupationally-related gender-free physical fitness standards.

132. **Woodhead, A. B.; Moynihan, M. E**. The effect of Aviation Officer Candidate's School on aerobic and anaerobic fitness.

133. **Wright, J. E.; Sharp, D. S.; Vogel, J. A.; Patton, J. F. III**. Assessment of muscle strength and prediction of lifting capacity in U.S. Army personnel.

STRENGTH TESTING

2. **Aghazadeh, F.; Ayoub, M. M**. A comparison of dynamic- and static-strength models for prediction of lifting capacity.

6. **Arnold, J. D.; Rauschenberger, J. M.; Soubel, W. G.; Guion, R. M**. Validation and utility of a strength test for selecting steelworkers.

7. **Aume, N. M**. A machine for weight-lift testing.

24. **Caldwell, L. S.; Chaffin, D. B.; Dukes Dobos, F. N.; Kroemer, K. H.; Laubach, L. L.; Snook, S. H.; Wasserman, D. E**. A proposed standard procedure for static muscle strength testing.

28. **Chaffin, D. B**. Ergonomics guide for the assessment of human static strength.

29. **Chaffin, D. B.; Herrin, G. D.; Keyserling, W. M**. Preemployment strength testing: An updated position.

31. **Christ, C. B.; Boileau, R. A.; Slaughter, M. H.; Stillman, R. J.; Cameron, J**. The effect of test protocol instructions on the measurement of muscle function in adult women.

52. **Griffin, J. W.; Tooms, R. E.; vander Zwaag, R.; Bertorini, T. E.; O'Toole, M. L**. Eccentric muscle performance of elbow and knee muscle groups in untrained men and women.

59. **Jackson, A. S.; Osburn, H. G.; Laughery, K. R**. Validity of isometric strength tests for predicting performance in physically demanding tasks.

61. **Kannus, P.; Beynnon, B**. Peak torque occurrence in the range of motion during isokinetic extension and flexion of the knee.

63. **Keyserling, W. M.; Herrin, G. D.; Chaffin, D. B**. Isometric strength testing as a means of controlling medical incidents on strenuous jobs.

64. **Keyserling, W. M.; Herrin, G. D.; Chaffin, D. B.; Armstrong, T. J.; Foss, M. L**. Establishing an industrial strength testing program.

65. **Krock, L. P**. Russian Air Force: Pilot selection and retention procedures.

67. **Kroll, W.; Kilmer, W. L**. Coordination mechanism in fast human movements--Experimental and modeling studies. Volume 2.

68. **Kues, J. M.; Rothstein, J. M.; Lamb, R. L**. The relationships among knee extensor torques produced during maximal voluntary contractions under various test conditions.

81. **Mital, A.; Ayoub, M. M**. Modeling of isometric strength and lifting capacity.

82. **Mogenson, F. E.; Stobbe, T. J**. Investigation of the effect of exertion length on measured isometric strength.

97. **Robertson, D. W.; Trent, T**. Documentation of an occupational strength test battery (STB).

103. **Schopper, A. W.; Mastroianni, G. R**. Helicopter-referenced single control, center position force exertion capabilities of males and females.

112. **Stobbe, T. J**. A test-retest criterion for isometric strength testing.

113. **Su, C. Y.; Lin, J. H.; Chien, T. H.; Cheng, K. F.; Sung, Y. T**. Grip strength in different positions of elbow and shoulder.

116. **Teves, M. A**. Using research to match the soldier to the job.

117. **Teves, M. A.; Vogel, J. A.; Wright, J. E**. Comparison of male and female maximum lifting capacity.

124. **Walamies, M.; Turjanmaa, V**. Assessment of the reproducibility of strength and endurance handgrip parameters using a digital analyser.

129. **Wheeler, D. L.; Graves, J. E.; Miller, G. J.; O'Connor, P.; MacMillan, M**. Functional assessment for prediction of lifting capacity.

133. **Wright, J. E.; Sharp, D. S.; Vogel, J. A.; Patton, J. F. III**. Assessment of muscle strength and prediction of lifting capacity in U.S. Army personnel.

STRENGTH/FITNESS TRAINING

5. **Armstrong, D. S.; Berkman, B.; Floren, T. M.; Willing, L. F**. A handbook on women in firefighting: The changing face of the fire service.

13. **Balldin, U. I.; Myhre, K.; Tesch, P. A.; Wilhelmsen, U.; Andersen, H. T**. Isometric abdominal muscle training and G tolerance.

18. **Braith, R. W.; Graves, J. E.; Leggett, S. H.; Pollock, M. L**. Effect of training on the relationship between maximal and submaximal strength.

19. **Brown, C. H.; Wilmore, J. H**. The effects of maximal resistance training on the strength and body composition of women athletes.

30. **Charles, M. T**. Women in policing: The physical aspect.

31. **Christ, C. B.; Boileau, R. A.; Slaughter, M. H.; Stillman, R. J.; Cameron, J**. The effect of test protocol instructions on the measurement of muscle function in adult women.

34. **Coyle, E. F.; Feiring, D. C.; Rotkis, T. C.; Cote, R. W. III; Roby, F. B.; Lee, W.; Wilmore, J. H**. Specificity of power improvements through slow and fast isokinetic training.

36. **Drinkwater, B. L**. Women and exercise: physiological aspects.

40. **Dyer, F. N.; Burke, W. P**. Prediction of success in Airborne training.

41. **Epperson, W. L.; Burton, R. R.; Bernauer, E. M**. The effectiveness of specific weight training regimens on simulated aerial combat maneuvering G tolerance.

42. **Epperson, W. L.; Burton, R. R.; Bernauer, E. M**. The influence of differential physical conditioning regimens on simulated aerial combat maneuvering tolerance.

44. **Falkel, J. E.; Sawka, M. N.; Levine, L.; Pandolf, K. B**. Upper to lower body muscular strength and endurance ratios for women and men.

45. **Federal Bureau of Investigation Academy**. Physical fitness testing in law enforcement.

52. **Griffin, J. W.; Tooms, R. E.; vander Zwaag, R.; Bertorini, T. E.; O'Toole, M. L**. Eccentric muscle performance of elbow and knee muscle groups in untrained men and women.

53. **Hickson, R. C.; Hidaka, K.; Foster, C**. Skeletal muscle fiber type, resistance training, and strength-related performance.

71. **Lillegard, W. A.; Terrio, J. D**. Appropriate strength training.

76. **McDaniel, J. W**. Male and female capabilities for operating aircraft controls.

77. **McDaniel, J. W.** Strength capability for operating aircraft controls.

83. **Mullins, W. R.** Female combat helicopter pilot selection criteria.

96. **Reilly, R. R.; Zedeck, S.; Tenopyr, M. L.** Validity and fairness of physical ability tests for predicting performance in craft jobs.

105. **Shannon, R. H.** Biomechanics analysis of tasks involving manual materials handling.

106. **Shannon, R. H.** Determination of efficient methods of lift by comparing trained and untrained male and female lifters.

109. **Staron, R. S.; Karapondo, D. L.; Kraemer, W. J.; Fry, A. C.; Gordon, S. E.; Falkel, J. E.; Hagerman, F. C.; Hikida, R. S.** Skeletal muscle adaptations during early phase of heavy-resistance training in men and women.

110. **Stauffer, R. W.; McCarter, M.; Campbell, J. L.; Wheeler, L. F. J.** Comparison of metabolic responses of United States Military Academy men and women in acute military load bearing.

113. **Su, C. Y.; Lin, J. H.; Chien, T. H.; Cheng, K. F.; Sung, Y. T.** Grip strength in different positions of elbow and shoulder.

115. **Tesch, P. A.; Hjort, H.; Balldin, U. I.** Effects of strength training on G tolerance.

116. **Teves, M. A.** Using research to match the soldier to the job.

128. **Weigmann, J. F.; Burns, J. W.** Current concepts in female acceleration research.

132. **Woodhead, A. B.; Moynihan, M. E.** The effect of Aviation Officer Candidate's School on aerobic and anaerobic fitness.

STRENGTH/FITNESS RELATED TO AVIATION

1. **AGARD.** Recruiting, selection, training and military operations of female aircrew.

8. **Aume, N. M.; McDaniel, J. W.; Garver, T.** Human strength capabilities for the operation of parachute ripcords and riser releases.

11. **Baisden, A. G.** Gender and performance in naval aviation training.

13. **Balldin, U. I.; Myhre, K.; Tesch, P. A.; Wilhelmsen, U.; Andersen, H. T.** Isometric abdominal muscle training and G tolerance.

20. **Brown, W. R.; Dohme, J. A.; Wicke, D. C.** An evaluation of minority and female performance in Army Rotary Wing Aviation Training. Vol. II: Evaluation report.

22. **Bullock, M. I.** Ripcord release capability of female parachutists.

27. **Carretta, T. R.** Gender differences in USAF pilot training performance.

37. **Drinkwater, B. L.; Folinsbee, L. J.; Bedi, J. F.; Plowman, S. A.; Loucks, A. B.; Horvath, S. M.** Response of women mountaineers to maximal exercise during hypoxia.

37. **Drinkwater, B. L.; Folinsbee, L. J.; Bedi, J. F.; Plowman, S. A.; Loucks, A. B.; Horvath, S. M.** Response of women mountaineers to maximal exercise during hypoxia.

38. **Drinkwater, B. L.; Kramar, P. O.; Bedi, J. F.; Folinsbee, L. J.** Women at altitude: Cardiovascular responses to hypoxia.

41. **Epperson, W. L.; Burton, R. R.; Bernauer, E. M.** The effectiveness of specific weight training regimens on simulated aerial combat maneuvering G tolerance.

42. **Epperson, W. L.; Burton, R. R.; Bernauer, E. M.** The influence of differential physical conditioning regimens on simulated aerial combat maneuvering tolerance.

46. **Fischer, M. D.; Wiegman, J. F.; Bauer, D. H.** Female tolerance to sustained acceleration - A retrospective study.

49. **Gillingham, K. K.; Schade, C. M.; Jackson, W. G.; Gilstrap, L. C.** Women's G tolerance.

51. **Gragg, C. D.; Evans, C. B.; Gilliam, W. L.** Ejection seat testing for females.

62. **Karim, B.; Bergey, K. H.; Chandler, R. F.; Hasbrook, A. H.; Pursell, J. L.; Snow, C. C.** A preliminary study of maximal control force capability of female pilots.

65. **Krock, L. P.** Russian Air Force: Pilot selection and retention procedures.

66. **Kroemer, K. H. E.** Human force capabilities for operating aircraft controls at 1, 3, and 5 Gz.

70. **Leeper, R. C.; Hasbrook, A. H.; Purswell, J. L.** Study of control force limits for female pilots.

72. **Lyons, T. J.** Women in the fast jet cockpit--Aeromedical considerations.

73. **Lyons, T. J.** Women in the military cockpit.

76. **McDaniel, J. W.** Strength capability for operating aircraft controls.

77. **McDaniel, J. W.** Male and female capabilities for operating aircraft controls.

78. **McDaniel, J. W.; Robbins, G.** The strength of women for activation of ejection seat controls.

83. **Mullins, W. R.** Female combat helicopter pilot selection criteria.

86. **Newsom, B. D.; Goldenrath, W. L.; Winter, W. R.; Sandler, H.** Tolerance of females to +GZ centrifugation before and after bedrest.

99. **Rock, L. C.** Report of the study group on USAF female aircrew requirement for life support and protective clothing.

103. **Schopper, A. W.; Mastroianni, G. R.** Helicopter-referenced single control, center position force exertion capabilities of males and females.

104. **Schopper, A. W.; Mastroianni, G. R.** Simultaneous multiple control force exertion capabilities of males and females versus helicopter control force design limits.

114. **Surburg, R. R.; Williamson, C. B**. A study to establish physical fitness norms for female aviators.

115. **Tesch, P. A.; Hjort, H.; Balldin, U. I**. Effects of strength training on G tolerance.

128. **Weigmann, J. F.; Burns, J. W**. Current concepts in female acceleration research.

130. **Whinnery, A. M.; Whinnery, J. E**. The electrocardiographic response of females to centrifuge +Gz stress.

131. **Whitley, P. B**. U.S. Navy experience with females during acceleration research and G-tolerance training.

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This bibliography presents the results of a literature review to provide background information for the study "Performance-based Occupational Strength Testing for Candidate Navy Pilots/Naval Flight Officers." The purpose of this work is to develop an occupational strength test battery to establish gender-neutral standards in naval aviation selection. This research, partially funded by the Defense Women's Health Research Program, was prompted by a congressional decision to allow smaller statured individuals entry into military aviation. The long-range objective of this project is to test and identify individuals capable of meeting specific strength requirements to safely operate naval aircraft. The cited publications cover the time period from 1972 through October 1994. The literature search was conducted using the following databases: Defense Technical Information Center (DTIC), Medline, and PsychLit. The abstracts included in this bibliography are in original form. An index organized by subject matter is provided.

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Development of Gender-Neutral Occupational Standards
I. Physical Training Issues

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ABSTRACT
The increasing visibility of women in military operations has renewed interest in the debate of gender and modern combat operations. The change in Department of Defense (DoD) policy authorizing female aviators in combat squadrons raised questions regarding the objectivity and scientific evidence serving as the basis for gender exclusion decisions. An essential aspect of the debate are the criteria for combat readiness. Optimal job performance is fundamental for combat readiness, yet, the physical requirements associated with combat readiness in aviation have not been well defined. Efforts to develop gender-neutral standards for Navy pilots and flight officers are underway. Part one of this paper reviews the literature addressing strength and physical fitness standards related to combat aviation and examines some legal issues related to federal hiring practice requirements. Part two will then address the physiological requirements of operating high performance aircraft and review psychometric issues in developing gender-neutral, performance-based physical standards.

INTRODUCTION
The history of women in aviation spans over 200 years and is well documented. Their role in military aviation began during World War II when over two thousand women served as Women's Airforce Pilots (WASPS). It ended with the war in 1944 and was not resumed until 1973 when naval aviation training was opened to women. Because of the combat exclusion law enacted by Congress in 1948 women were restricted to non-combatant aircraft until it was repealed in 1991.

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Women presently constitute 2.58% of the total Navy pilot population. This small percentage is due in part to the combat restrictions. Changing population demographics, federal hiring practice requirements, and the increasing roles of women in combat-related flying are expected to increase this proportion. Aviation applicants are screened to ensure aeronautical adaptability, success in training, aircraft compatibility, and long term aviation potential. Screening tests include intelligence testing, aeronautical adaptability, psychological adaptability, health evaluations and physical fitness. Pilot selection measures were developed on predominantly male populations. Much work has been done on the predictive equity of the written tests used by the services to select aviation candidates (5, 9, 13). Only recently have investigators addressed the physical, physiologic, and medical differences between men and women which affect their ability to tolerate the stresses of the aviation environment (1, 14, 24). The current physical fitness and strength screening process for naval officers has been used for many years although little or no research has been done to determine correlation between the fitness and strength requirements in training and operational aviation environment.

NAVY PHYSICAL STANDARDS
The rationale for the Navy's physical standards is the need to ensure combat readiness and personal effectiveness. Current standards for all Navy personnel place upper limits on body fat as assessed from various anthropometric

Appendix (b)

measurements. For accession screening, the Navy uses height and weight tables. For retention, Navy personnel are evaluated regularly for height, weight, and are required to perform tests of aerobic fitness. Anthropometric standards (height, sitting height, functional reach, buttock knee, and buttock leg length) are also used to screen aviation applicants for ability to safely fly naval aircraft.

In contrast to past standards which were designed to exclude underweight or chronically ill, current standards address excess weight and functional anthropometry in the military population. The rationale is that the measures are correlated with performance of military duties and overall health (17). Physical requirements, however, vary from service to service. Within the services, the standards for weight and anthropometry are significantly different for men and women. These widely disparate variations in physical requirements for performance across the services, and between men and women, require explanation and emphasize the need for gender-neutral, performance-based standards.

Marriott and Scott (17) provide a comprehensive review of military physical standards, their origins, measurement reliabilities, and population validities. They found the current physical fitness test was an appropriate indicator of physical fitness but was not representative of most military jobs. The relationship between body fat content and physical performance was inconsistent. They, therefore, recommended body composition standards be based primarily on ability to perform required physical tasks and secondarily on long-term health consideration.

Naval Aviation Training

Aviation students undergo physical fitness training as part of their initial curriculum. Students are tested at onset, given training to improve weak areas, and retested several weeks later. At present the minimums for men are 50 sit-ups, 42 push-ups, 1.5 mile run in 12 minutes, 12 foot wall climb, and 8 foot wall climb. The minimums for women are 45 sit-ups, 17 push-ups, 1.5 mile run in 15 minutes, 12 foot wall touch, and 6 foot wall climb. Obstacle course times are renormed periodically and are normed by gender. Current cut-off scores are 3.5 minutes for men and 4.9 minutes for women. The tests are general physical fitness tests typically used to measure strength and endurance and have not been validated against specific aviation tasks.

Physical fitness standards were waived for the first women in naval aviation. Women also encountered problems with body strength during survival training in physically pushing off the plane canopy and inflating and climbing into life rafts. Efforts to correct these problems led to new norms and aerobic measures in physical fitness training, equipment modifications, and new water survival techniques (26).

Effects of Training on Physical Fitness

Studies by Baldi (6) and Thomas (27) have found female cadets at the service academies perform much better in physical fitness examinations, had less percentage of body fat and were well above average in maximal oxygen uptake in comparison of women in the general population. Physical performance is affected by previous physical conditioning and athletic ability and experience. Seventy-five percent of female students at the academies have previous athletic experience. Actual fitness tests at the service academies are the same for men and women, but women are graded on a different scale. Male and female cadets have shown consistent improvement in performance on the fitness tests. Most striking has been improvement in the number of push-ups (111% for women, 42% for men) and sit-ups (26% for women, 3% for men (23). Training programs have reduced gender differences in aerobic power (10). Weight training has resulted in significant gains in strength (8). Standards have been upgraded several times and the tests have changed over the years to reflect those improvements.

JOB PERFORMANCE AND PHYSICAL FITNESS

Occupational physical standards: Air Force, Army, Navy

Research programs to establish gender-free, occupationally-related physical fitness standards gained momentum in the 1970s. This change was due in part to the need to utilize increasing numbers of women in non-traditional specialties that had been closed to women because they were presumed to be too physically demanding. The Army and Air Force have since categorized most enlisted specialties into physical demand categories. The development of test batteries for evaluating the compatibility of an individual's physical capacities with the physical demands of the various Air Force Speciality codes has been described in detail (4). The Air Force currently uses these demand categories for occupational selection and assignment and the Army is considering reimplementation (30). The Army's step-by step process is described by Vogel, Wright, and Patton (28) and Vogel, Wright, Patton, Dawson, and Eschenback (29).

Job-related physical training standards are currently being developed by the Naval Medical Research Institute for the Fleet Diving Program (16). The standards to be used for entry, graduation, and physical screening will be based on a test battery which has been developed using a task analytic approach.

Several Navy studies have demonstrated the relationship between physically demanding shipboard tasks and physical fitness measures, such as arm pull and lift (25), arm curl and leg press strength (15), Navy Physical Readiness Test scores and lean body mass (7). Although there has been some determination of physical strength standards for shipboard jobs, they have not been incorporated in manpower requirements and have not been used as screening or selection devices in crew training.

The 1992 decision to allow women to serve on Navy combatants renewed concerns. Gender-free job standards were developed utilizing a human systems integration approach which included anthropometrics, biomechanics, and medical requirements (22). Task analyses identified critical operations. Approximately 55 percent of the tasks were difficult or impossible for the women to perform. Design deficiencies contributed to significant human performance and safety issues for both males and females in 30 percent of tasks. Weight training, job-specific training, job aids, equipment modification or redesign, and properly fitting gear resolved most problems. Where job accommodation was not possible, gender-neutral strength requirements were recommended.

McDaniel and colleagues have conducted a number of studies addressing strength and physical fitness issues associated with combat aviation. These studies, which will be discussed in greater detail in Part II, have examined strength and endurance (18) as well as strength capabilities for operating aircraft controls (19, 20), parachute ripcords and riser releases (3), and activitation of ejection seats (21).

LEGAL ISSUES

Employment testing is governed by legislation to ensure that individuals are judged on the merits of their abilities and not on the basis of disability, race, sex, national origin, religion, or sex . The following impose legal requirements that select: standards and criteria, are job related and consistent with business necessity.

An amendment to Title VII of the Civil Rights Act of 1964 protects the right of an employer to give a test provided it was not designed, administered or used to discriminate because of race, color, religion, sex, or national origin. Uniform Guidelines on Employee Selection Procedures offer a uniform Federal position on employment practices for employers to determine through validation studies, whether their employment tests are job related (11). The fundamental principle underlying the Guidelines is that an employment selection device such as a physical test can be challenged if it has an "adverse" or "disparate" impact on employment opportunities of any race, sex, or ethnic group unless justified by business necessity. A selection rate for a protected group that is less than 80% of the rate for the group with the highest rate will generally be regarded as evidence of a test's disparate impact. This rule is known as the "4/5 ths rule". If those challenging a test can show that it has disparate impact, it then becomes the employer's responsibility to demonstrate test validity. Normally, this means by validation, which demonstrates the relationship between the selection procedure and performance on the job. There are three types of validity: criterion, content, and construct. Construct validity has been regarded as inapplicable by definition to job duties requiring physical abilities. Predictive (criterion-related) and job simulation-tests (content validity) are both widely accepted and meet legal standards. Some exercise physiologists have developed job standards that are based on complex measures of the energy costs associated with tasks and claim that their criterion-linked standards are more defensible in court (2). Others feel that content-based physical fitness tests that simulate or replicate job functions are more readily described and defended before a judge or jury (12).

Under the Americans with Disabilities Act (ADA) in 1992, employers may not refuse to hire nor may they discharge an individual with a disability because of that disability, unless that person, with or without a reasonable accommodation, is unable to perform the essential functions of the job.

The Civil Rights Act of 1991 makes it illegal for an employer to adjust the scores of or use different cutoff scores for employment related tests on the basis of gender. This law, therefore, renders fitness tests that have different standards or passing scores for men and women legally indefensible.

The Age Discrimination in Employment Act prohibits mandatory age-based retirement. The correlation of age and physical performance must be proven.

CONCLUSIONS

Military jobs are opening to a wider segment of the general population. Because 90% of the specialized military tasks have traditionally been performed by males, most equipment was designed around anthropometry for this population segment. As smaller statured individuals, particularly women, are integrated into these jobs, and asked to operate the same equipment, screening standards must be developed to assure the safety of all involved.

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BIOGRAPHIES

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Development of Gender-Neutral Occupational Standards
II. Job Demands and Physiological Issues

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ABSTRACT
Regardless of gender, high performance aircraft present multiple and complex physical challenges. Combat scenarios involve exposure to accelerative and decelerative forces that may be both substantial and rapid in onset. Gender differences in muscle strength and aerobic capacity related to these unique occupational stresses are described. Past and current efforts to identify performance capabilities relevant to the development of gender-free occupational standards are cited.

INTRODUCTION
High performance aircraft impose unique physical demands on the pilot regardless of gender. These demands include significant isometric or static contributions from the neck muscles (weight-bearing of helmet and head-mounted apparatus), the muscles of respiration, the abdomen and the thighs (anti-G straining maneuvers), and the upper body (actuating the ejection seat) (36). That women in general have less muscle strength and lower aerobic capacity than men raises questions of performance capabilities. Gender-neutral occupational physical standards should be established for physical fitness components and should be based on objectively determined physical demands of the job.

PHYSIOLOGICAL GENDER DIFFERENCES
Physiologically, there are three distinct energy sources (stored, anaerobic metabolism, aerobic metabolism) used by the body to perform work during exercise. These sources rely on anabolic and catabolic chemical reactions that are gender neutral. However, three of the components of physical fitness (muscular strength, anaerobic power, aerobic capacity) have been shown to be distinctly different between males and females. Laubach (14) reviewed the literature reporting comparable static and dynamic muscle strength measurements between men and women and found wide ranges of percentage differences between genders. These data and findings by Sharp and Vogel (31) and Lyons (16) are summarized below.

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Gender Differences in Physical Capacity

<u>Muscle strength:</u> The maximal force developed during a single contraction.

•Women have 35-85% of the strength of men depending on the muscle group.

•Women produce 60-65% of the isometric force and isokinetic torque as men on certain muscle tests.

•Traditional weight training results in strength gains of 16%.

<u>Anaerobic Power:</u> Muscular power or the capacity to produce energy for brief, high-intensity exercise measured on the Wingate bicycle ergometer test.

Appendix (c)

•Women generate 65% of peak power of men on the Wingate test (90% adjusted for fat-free mass).

•Women generate 60% of mean (30 sec) power as men on the Wingate test (83% adjusted for fat-free mass).

Aerobic Capacity: Maximal oxygen uptake, stamina.

•Women have 75% that of men (79% adjusted for lean body mass).

Many of the different strength measurements do not correlate with each other. Even strength measurements for specific muscles vary with the method of measurement. For example, dynamic plantarflexion in women averages 86% that of men, whereas, the force of pushing back with the toes is only 35% as strong as men (14). This particular movement may be confounded in a cockpit that does not adequately accommodate a small person (11). Most gender differences in strength are accounted for by a greater size and lean body mass in males (16). The larger pilot may perform better with the occurrence of hydraulic failure in some aircraft when muscular strength is important, but differences may not be as important in modern fly-by-wire aircraft. As with aerobic work, allowance for lean body mass abolishes most of the gender differences in lifting and carrying capacity (25). The same is true for female mean power and peak power as measure on the Wingate test (25).

Men's isometric strength peaks at age 30, decreases slowly for 20 years and decreases rapidly after that. Women's isometric strength peaks at age 20, declines slowly, then more rapidly between 45 and 65 years of age. Male strength loss with aging is associated with a decrease in fat-free mass and testosterone, while women's strength loss occurs during the menopausal years (31). Maximum lifting strengths as a function of gender, age, and body composition have been described by Sharp and Vogel (31).

Isometric strength testing has commonly been used to evaluate and match human strength capability to job strength requirements. The literature addresses standardized data collection and results reporting (2), methodology for increasing reliability (34), validity and fairness (10).

Shvartz & Reibold (32) used aerobic fitness norms for males and females in the United States, Canada, and Europe to establish absolute and relative maximal oxygen intake norms in males and females aged 6 - 75 years. Norms for maximal oxygen intake were established for seven fitness categories. Gender differences varied according to age. Mean maximal oxygen intake in absolute terms (L/min) for males showed an increase with age to a plateau of 3.4L/min at 18 years after which it declined to 3.2 and 2.7 L/min for ages 30 and 50. The corresponding values for females were 2.2, 2.1, and 1.8 L/min. Gender differences for relative (ml kg^{-1} min^{-1}) maximal oxygen intake were smaller. Mean values for males for the above ages were 50, 48, 35 (ml kg^{-1} min^{-1}) respectively, with corresponding values for females of 44, 41, 28 (ml kg^{-1} min^{-1}), respectively

DEVELOPING VALID STANDARDS

Job Analysis - Methodology

Job analysis describes a system by which physically demanding occupations can be assigned on a gender-neutral basis that will be scientifically defensible. Butterworth (1) offers a good historical review of job analysis and Guion (9) provides detailed steps to transition from job analysis to establishing test specifications for assuring job relevance. The following steps briefly summarize the process:

1. Conduct job task analysis. Job analysis is a scientific methodology of verifying job tasks, their frequency and importance; performance standards; and skills, abilities and competency required.

2. Define essential functions. If removal of a function fundamentally alters that position, the function is essential.

3. Identify physical abilities within each essential function. These may include speed (anaerobic capacity), strength, stamina, endurance, flexibility, balance, and small motor movements.

4. Devise tests or measures of one's ability to successfully complete the physical tasks. Tests are generally of two types: abstract ability, which predicts ability to perform essential functions, and performance simulation, which requires demonstration of physical skills. Tests should assess the entire range of physical abilities required on the job and should incorporate techniques that may be used to compensate for strength differences. Federal guidelines specify test tasks require minimal training or knowledge of test equipment.

5. Establish standards. Standards should be based on the performance distribution of the population and operational requirements. Gender norming or the adjusting of scores on employee related tests undercut the job relatedness of the standard and violate the Civil Rights Act of 1991. There is a move away from using norm-referenced standards toward the use of criterion -referenced standards as the evaluation method of choice among fitness tests. Although theoretically sound, there is

little empirical evidence to support the validity of these criterion standards (McDermott, 1991).

Job Analysis - Naval Aviation
Naval aviation job tasks analyses are limited in number. During 1972, the Naval Aerospace Medical Research Laboratory conducted a series of investigations analyzing the operational functions of the naval flight officer (NFO). A major part of that series involved the determination of the tasks performed by the NFO in various aircraft. A Function Description Inventory was developed for each of the NFO positions. A compendium of functions encompassing the duties and tasks required by the operational NFO communities was developed by Doll (5). Comparable studies of naval pilot tasks analyses are unknown.

Early Navy Efforts
In 1976, the Navy initiated research in collaboration with the Air Force to ascertain maximal strength capabilities and requirements for various cockpit controls for men and women. Waivers had been granted to the first female applicants for naval aviation training relative to physical strength requirements. Objective data for men and women were needed to correlate body strength requirements relative to aircraft flight controls. Specifically, the studies would determine the strength required to perform these physical functions: 1) apply necessary force in performing normal and emergency maneuvers including conditions of failed hydraulic assist, 2) apply maximum braking force for a sufficient duration, 3) maintain a constant rudder force in case of an engine-out condition or other related mechanical problems for an adequate duration in order to land safely and, 4) apply necessary force to activate controls associated with emergency ejection while maintaining correct body posture, to continue to grip the actuator handle during ejection to prevent arms from flailing, and to manually open and close the canopy.

Aviation Pilot Testing Devices were constructed to represent cockpits of yoke-controlled (multi-engine), stick-controlled (single engine) and stick/collective controlled (helicopter) aircraft. Data were to be correlated with standard physical fitness test criteria for aviation officer candidates and the resulting data would be compared with existing military standards requirements for aircraft control resistances.

Background, applicable literature, and methodology of this pilot strength and endurance screening program are described by McDaniel (17, 18, 20). Although this project was discontinued due to lack of funds, it has provided a starting point for the Navy's current efforts to develop gender-neutral occupational physical standards.

Control Force Limits
Several studies have measured aircraft control forces, control movements, and basic motion that should be useful in job task analysis. In the early 1970s, the Federal Aviation Administration (FAA) examined required levels of force on the elevator, rudder, and aileron, endurance times for holding control forces, and anthropometric parameters for civil aviation aircraft with regards to female pilots. The data showed that the limits on the forces required for aircraft controls for general aviation aircraft as outlined in the Flight Aviation Regulations (FAR) were too high for most U.S. female pilots when compared to known strength measurements of women (18). The authors noted there was no information on the origin of the FAR force limits by which to judge the validity of Regulations with respect to the capacity of the pilot population or to flight situations.

Schopper & Mastroianni (30) studied the capability of pilots to manipulate multiple flight controls simultaneously in emergency situations that simulated loss of mechanical assistance for flight control manipulation (30). In their study, 50% of the men and 90% of the women failed to meet strength requirements. However, reports of pilots (men and women) who meet current FAA standards and have had difficulty manipulating aircraft controls because of strength deficiencies are extremely rare (24).

FAST-JET PHYSICAL DEMANDS
Physical demands unique to flying high-performance aircraft include actuating the ACES-II ejection seat, maintaining head posture during high-G maneuvers, and exerting anti-G straining maneuvers.

Ejection Seat
Several studies have documented the aerodynamic characteristics of the ACES-II ejection seat and anthropometric accommodation of a female population (21, 23, 29).

Neck Strength
Limited centrifuge data are available for assessing problems with female neck strength. Although females possess 12% greater neck range of motion, 11% faster neck muscle reaction time, and 60% less neck strength, none of the data show a condemnation of either gender's neck strength for aerial combat (37). A blend of technique, skill, and strength all play a role in success. Whitley's (37) studies found that 44% of aircrew indicated neck pain interfered with their mission performance.

G-tolerance
The male physiologic response to high sustained +Gz during simulated air combat maneuvers has been directly related to increased muscular strength (6, 35). Anaerobic capacity, a function of muscular strength and muscular endurance, was reported to account for at least 60% of the variance in high G-duration time for males (38). Studies to determine if the same relationships exist for women are ongoing (38).

Individuals exposed to the high-G environment of fighter aircraft must perform a straining maneuver in order to resist the effects of G forces. The anti-G straining maneuver (AGSM) consists of tensing abdominal and skeletal muscles of the extremities for 3-second periods. Physiological limitations can impede the pilot particularly in air combat maneuvering which is composed of repeated episodes of high sustained +Gz. A number of investigators have studied the influence of physical fitness and related parameters on G-tolerance (6). Physical training appears to have little effect on relaxed G tolerance when no straining maneuvers are involved. Specific abdominal muscle conditioning has been found to potentiate G tolerance (33). Significant increases in maximal oxygen uptake, muscular strength, acceleration tolerance, and reductions in G-fatigue indicate weight training will improve human tolerance to air combat maneuvers (6, 35).

Isometric strength and endurance, like that required to perform the anti-G straining maneuver, have been described for gender differences (26) and menstrual cycle effects (27). Generally, women displayed less strength, but greater muscular endurance, than their male counterparts. Strength did not vary with menstrual phase, while muscular endurance varied only in women not taking oral contraceptives. In another study, G-tolerance was influenced negatively by height and positively by weight (8). When height and weight were accounted for, there were no gender differences.

Significant gender differences at the +8Gz level have been attributed to differences in muscular strength and/or anti-G suit misfit that reduce the intensity of the muscular effort required for the anti-G straining maneuver (7).

Pilots and pilot candidates for Russian high performance aircraft are subjected to extensive physical examination and a monthly battery of physiological tests to substantiate their ability to tolerate +Gz stress. A static function test using a Statoergometer is used to predict required strength in legs and abdomen to counter acceleration stress. A centrifuge performance test that simulates main dynamic control characteristics of fourth generation fighter aircraft is used to estimate individual capabilities and evaluate undetected pathology, principally cardiovascular, to +Gz (12). If pilots do not meet strength criterion levels, they are placed on a strict physical training regimen and are not allowed to fly until strength tolerance is demonstrated.

Retrospective comparisons of sustained acceleration research and centrifuge training led the Presidential Commission on the Assignment of Women in the Armed Forces (28) to conclude that women do not demonstrate reliable differences in physiological or psychological responses to acceleration exposure compared to men. Physiologic risks profiles for men and women have more similarities than differences.

CURRENT RESEARCH DIRECTIONS

Current research directions involve three-dimensional, interactive, computer-graphics models of aircraft pilots to evaluate existing or conceptual crewstation design for fit, visual field, strength for operating controls, and reach capability with the arms and legs (19). The human body model reflects size (1st to 99th percentile) and proportions of men and women, the encumbrance of clothing and person protective equipment, and limitations for lap belts and shoulder harnesses. Anthropometric surveys of military pilots provided the underlying database (13). Reviews of biomechanical models to predict human static strength requirements have been discussed by Chaffin & Erig, M. (4) and Chaffin (3).

The Naval Aerospace Medical Research Laboratory is currently conducting studies to develop performance-based occupational strength standards for candidate Navy pilot and naval flight officers. This program will build on previous experience and develop gender-neutral standards to ensure the Navy places individuals in aviation roles who can safely perform all assigned tasks. The result of this research will be a strength screening tool that replicates critical aviation tasks, a pre-screening protocol to be fielded at remote sites (e.g., Naval Academy, ROTC units), and a remedial weight training program.

CONCLUSION

Combat exclusions that had closed some jobs to women have now been rescinded. Opponents to increasing the roles of women in the military frequently cite potential decreased military effectiveness because of physical limitations. Advocates argue improved technology decreases those concerns. The key to gender-neutral occupational standards is ability to perform the task and not political concerns. Gender and stature related strength differences have been documented. Expanding entry standards for occupational fields where strength critical tasks exist needs to be accomplished with safety as a paramount issue. Increased emphasis in women's athletics, fitness training, and specific physical conditioning has been shown to improve performance in general, and on specific tasks requiring physical strength and endurance. However, physical limitations are evident in all segments of the population, and unless limits and requirements are quantified and correlated, on the job safety cannot be ensured.

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DRAFT

ABSTRACT

MECHANICAL ANALYSIS OF THE MOVEMENTS USED IN THE T-34 LANDING GEAR CRANK AND CANOPY

Kim Van Fleet, Cynthia L. Tant, PhD, Pam Phipps, David Moulder, & LCDR Thomas L. Pokorski

For many years, there have been no strength standards for aviators, even though it has been suggested as an important variable in the operation of an aircraft. The purpose of this study was to determine the movements, joint reaction forces and joint moments required for successful landing gear and canopy release operation in the T-34. Two males and 1 female subject were selected because of different anthropometric characteristics (height: 186.7 cm - 160.0 cm). The subjects were videotaped from two views executing the landing crank turn and the canopy release. After taping, the images were captured, digitized, transformed, and smoothed with the Ariel Performance Analysis System. A significant difference was found between the forces obtained in a simulator cockpit and the actual T-34 cockpit. Increased joint reaction force was noticed in all four phases in the T-34 and during Phase 3 (0600-0300 position). SUB3 (short-female) had difficulty completing the 41 turns and produced the lowest force and torque during Phase 3. Because of the smaller stature, SUB3, was asked to perform critical tasks beyond the range of motion and/or strength of the individual. During the canopy release SUB3 produced the greatest linear displacement (Y) to reach the canopy but significantly less force then SUB1 and SUB2. All subjects were able to execute the canopy release with little difficulty. It appears, that in training with the simulator, the actual force of lowering the landing gear is not similar to the strength needed in the T-34 cockpit.

Appendix (f)

MECHANICAL ANALYSIS OF THE MOVEMENTS USED IN THE T-34 LANDING GEAR CRANK AND CANOPY

Kim Van Fleet, Cynthia L. Tant, PhD, Pam Phipps, David Moulder, & LCDR Thomas L. Pokorski

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Appendix G

Strength and Endurance Variables

<u>Isokinetic Resistance Exercise</u> - having a fixed speed of movement with a variable resistance accommodating to the individual throughout the range of motion.

<u>Concentric Muscle Loading</u> - a shortening muscle contraction where the muscle fibers actually shorten.

<u>Peak Torque</u> - the greatest torque generated by a muscle contracting through a range of motion.

<u>Torque Acceleration Energy (TAE)</u> - the total work in the first 1/8 of a second of a contraction through a range of motion.

<u>Total Work</u> - the total work performed during a series of muscular contractions regardless of speed of movement, range of motion, or time.

<u>Average Power</u> - the total work divided by the time it takes to perform the work.

Appendix H

Anthropometric Variables

Stature - the vertical distance between the standing surface and the top of the head.

Height, Sitting - the vertical distance between the sitting surface and the top of the head.

Eye Height, Sitting - the vertical distance between the sitting surface and the outer corner of the eye.

Acromial Height, Sitting - the vertical distance between the sitting surface and the tip of the shoulder.

Thigh Clearance - the vertical distance between the sitting surface and the highest point on the top of the thigh.

Abdominal Extension Depth - the horizontal distance between the anterior point of the abdomen and the back at the same level.

Hip Breadth, Sitting - the most lateral points on the hips or thighs, whichever are greater.

Thigh Circumference - the circumference of the thigh at its juncture with the buttock made perpendicular to the log axis of the thigh.

Knee Height, Sitting - the vertical distance between the footrest surface and the top of the knee.

Buttock-Knee Length - the horizontal distance between the back of the buttock and the front of the knee.

Bideltoid Breadth - the greatest horizontal distance between the outside edges of the deltoid muscles on the upper arms.

Thumbtip Reach - standing with shoulders against a wall, the horizontal distance between the back wall and the tip of the thumb when the arm is stretched forward horizontally.

Functional Leg Length - with the leg fully extended, the straight-line distance between the footrest surface and the back surface of the body.

FY96 Budget
without DWHRP $$

Rate	Position	% time	Salary			Total
O-4 T. Pokorski	Principal investigator	25				
E-5 J. Engle	Hospital corpsman	25				
GS-11 S. Meyer	Research Physiologist	25	$13,757			
GS-11 J. Saxton	Research Physiologist	25	$13,027			
GS-11 P. Collyer	Computer/software support	25	$13,757			
E-5 M. Stiney	Hospital Corpsman	25				
GS-5 P. Tracy	Clerical support	33	$9,441			
						$49,982
Rate	Position	% time	Overhead			
GS-11 S. Meyer	Research Physiologist	25	$7,250			
GS-11 J. Saxton	Research Physiologist	25	$7,250			
GS-11 P. Collyer	Computer/software support	25	$7,250			
GS-5 P. Tracy	Clerical support	33	$9,627			$31,377
Rank	Position	% time	Overhead			
O-4 T. Pokorski	Aerospace Physiologist	100	$29,000			
E-5 J. Engle	Hospital Corpsman	50	$14,500			
E-5 M. Stiney	Hospital Corpsman	50	$14,500			$58,000
Contracts/IPAs		25	$36,250			$36,250
				Grand Total		$175,609

8/14/95

Appendix (i)

DWHRP Budget
Performance-based occupational strength standards

Rate	Position	% time	Salary			Total
O-4	Principal investigator	100				
E-6	Hospital corpsman	100				
GS-11	Research Physiologist	100	$55,027			
GS-11	Research Physiologist	100	$52,108			
GS-11	Computer/software support	100	$55,027			
GS-11	Fabrication	25	$14,903			
GS-5	Clerical support	100	$28,351			$205,416
Rate	Position	% time	Overhead			
GS-11	Research Physiologist	100	$26,266			
GS-11	Research Physiologist	100	$26,266			
GS-11	Computer/software support	100	$26,266			
GS-11	Fabrication	25	$6,571			
GS-5	Clerical support	100	$26,266			$111,635
Rank	Position	% time	Overhead			
O-4	Aerospace Physiologist	100	$26,266			
E-5	Hospital Corpsman	100	$26,266			$52,532
Type	Period	% time	Salary	Overhead		
IPA Physiologist	Sep 1995-Sep 1996	100	$100,000	$26,266		
IPA Biomedical Technology PhD	Sep 1995-Sep 1996	25	$19,000	$6,567		
Research assistant	Oct 1995-Oct 1996	100	$32,000	$26,266		
Student Aid	Oct 1995-Oct 1996	100	$25,500	$26,266		
Graduate student Physics	Oct 1995-Oct 1996	50	$15,300	$13,133		
			$191,800	$98,498		$290,298
Destination	# Trips	# individuals trav	# days/trip		Travel cost	
NAS Whiting field	1	6	21		$5,000	
Naval Academy	1	6	14		$18,000	
Washington, DC	2	1	2		$1,600	
Training	1	4	4		$7,000	

Appendix (j)

7/12/95

DWHRP Budget
Performance-based occupational strength standards

Dayton, OH: USAF liason, Training	2	2	3		$3,200	
Professional Conferences	1	4	5		$6,000	
						$40,800
	Cost	Maintenance/yr				
Mobile Lab		$1,000				
*site set-up	$2,000					
*transportation to/from sites	$6,000					
*utilities at sites (~100 days)	$1,000					
ADP						
Maintenance		$1,000				
*Hardware	$4,000					
*Software/upgrades	$4,000					
Expendable supplies	2000					
	$19,000	$2,000				$21,000
	USAF ergonomics lab: to finish strength screening device					$100,000
Patuxent River personnel -finish force measurements						$50,000
				Grand Total		$871,681
			Overhead Total		$262,665	
			Overhead rate		$14.80/hour	

7/12/95